Subarachnoid Hemorrhage:
Management of Ruptured Cerebral Aneurysms

Michael W. Robinson, MD, PhD
Neurosurgeon

MAYFIELD
Brain & Spine

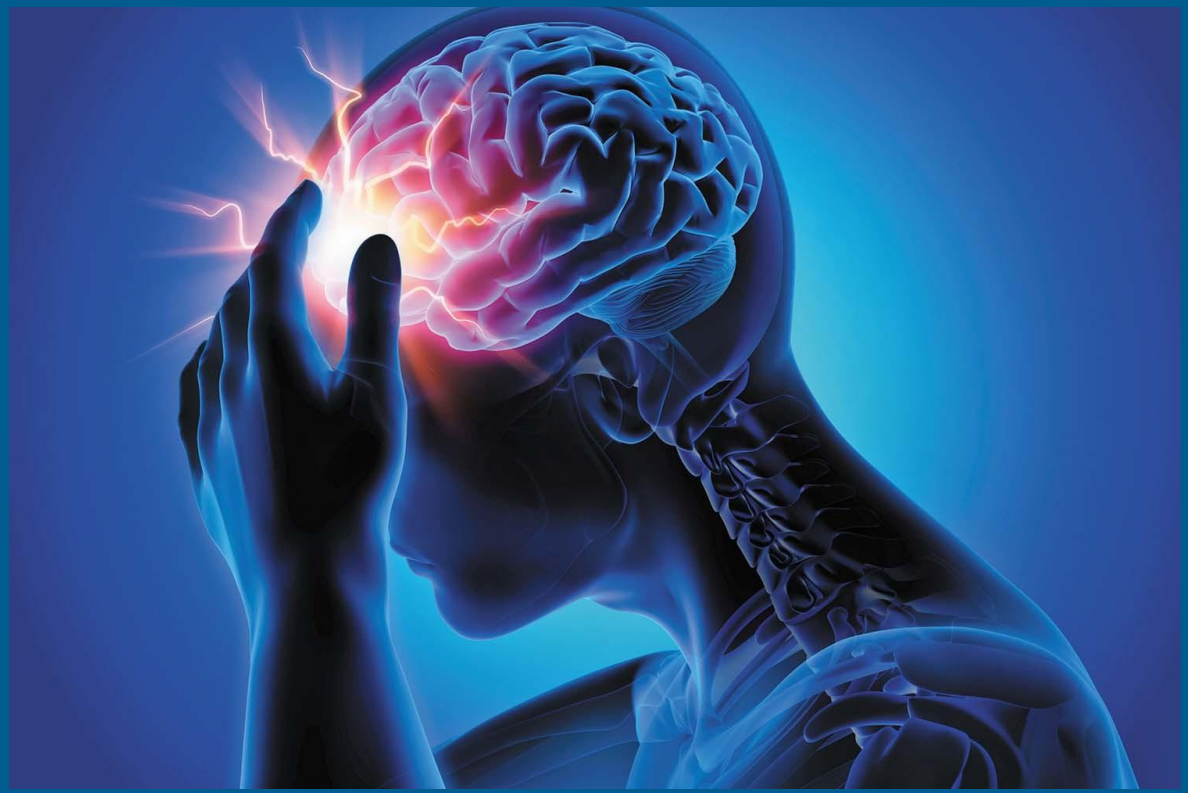
Ischemic

Hemorrhagic

SAH

Subarachnoid Hemorrhage

- **Aneurysmal SAH**



Subarachnoid Hemorrhage

- Aneurysmal SAH
- Trauma
- Brain vascular malformation (AVM, dAVF, cavernoma)
- Brain venous pathology – venous sinus thrombosis
- Perimesencephalic SAH
- Vasculopathy (RCVS, arterial dissections, amyloid angiopathy)
- Coagulopathic spontaneous SAH
- Infectious (mycotic) aneurysm

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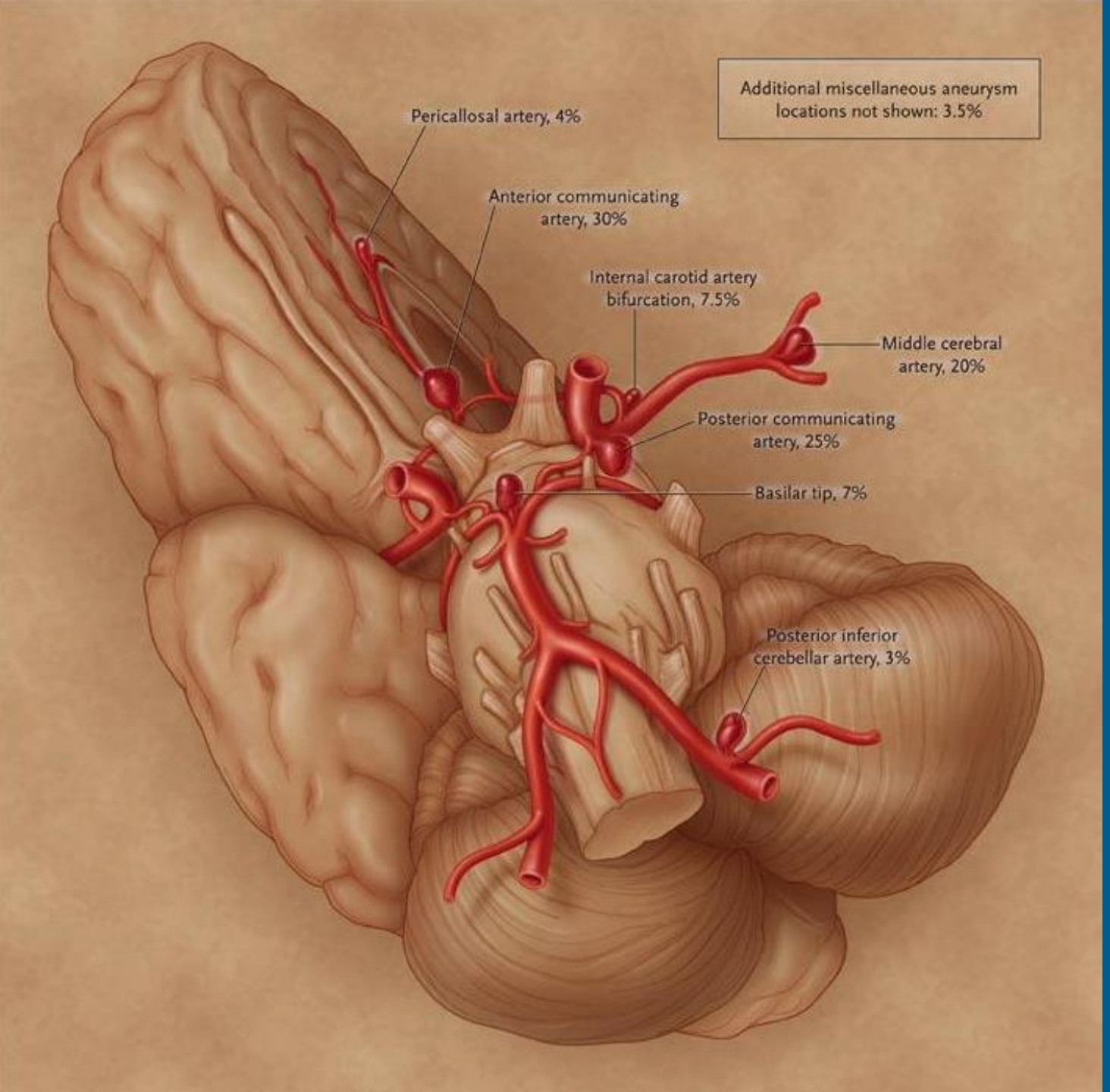
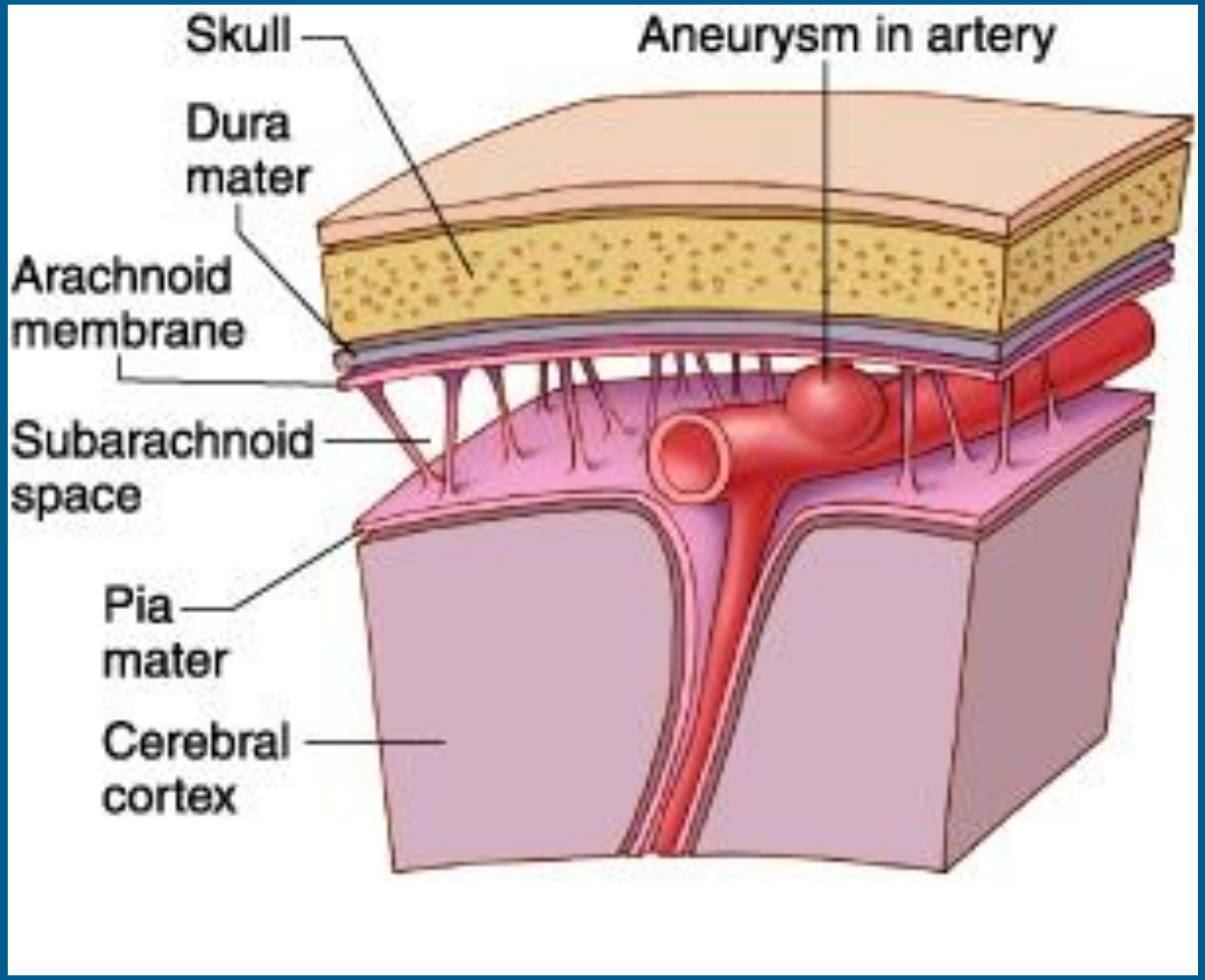
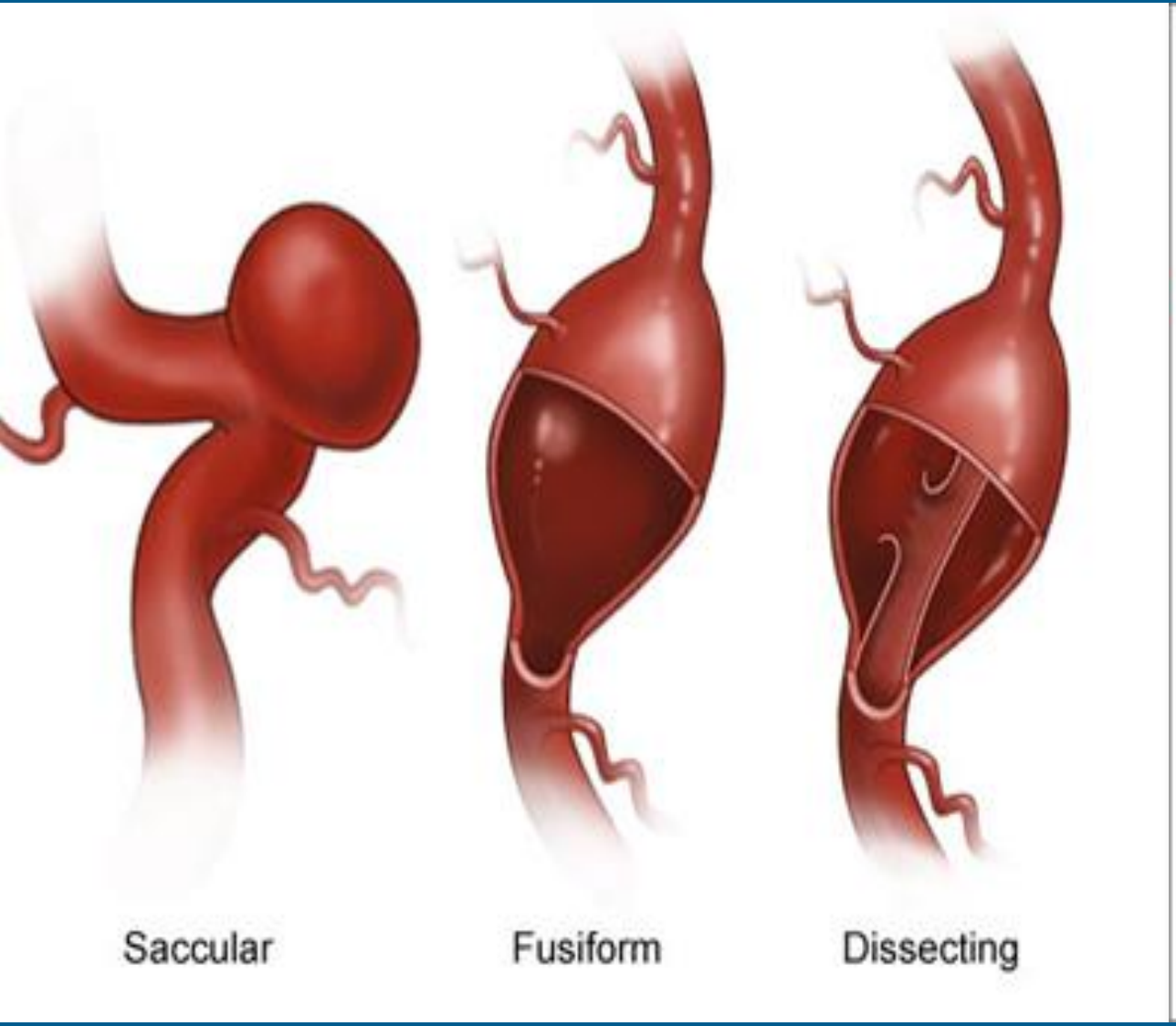
Goals

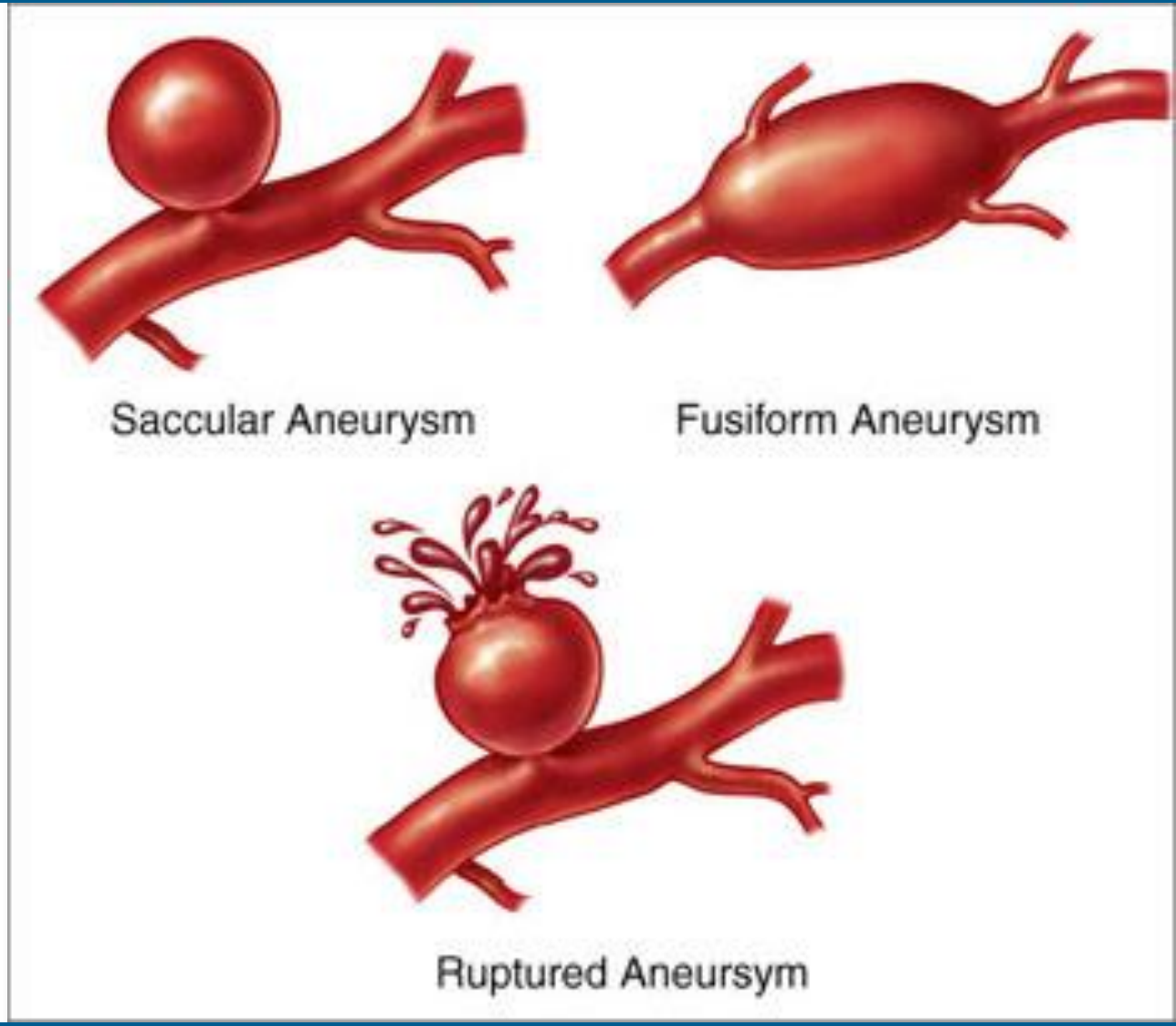
1. Understand the Etiology of Cerebral Aneurysms
2. Comprehend the Natural History of Cerebral Aneurysms
3. Identify Risk Factors for Aneurysm Rupture and Vasospasm
4. Comprehend Treatment Options & Potential Complications and Outcomes

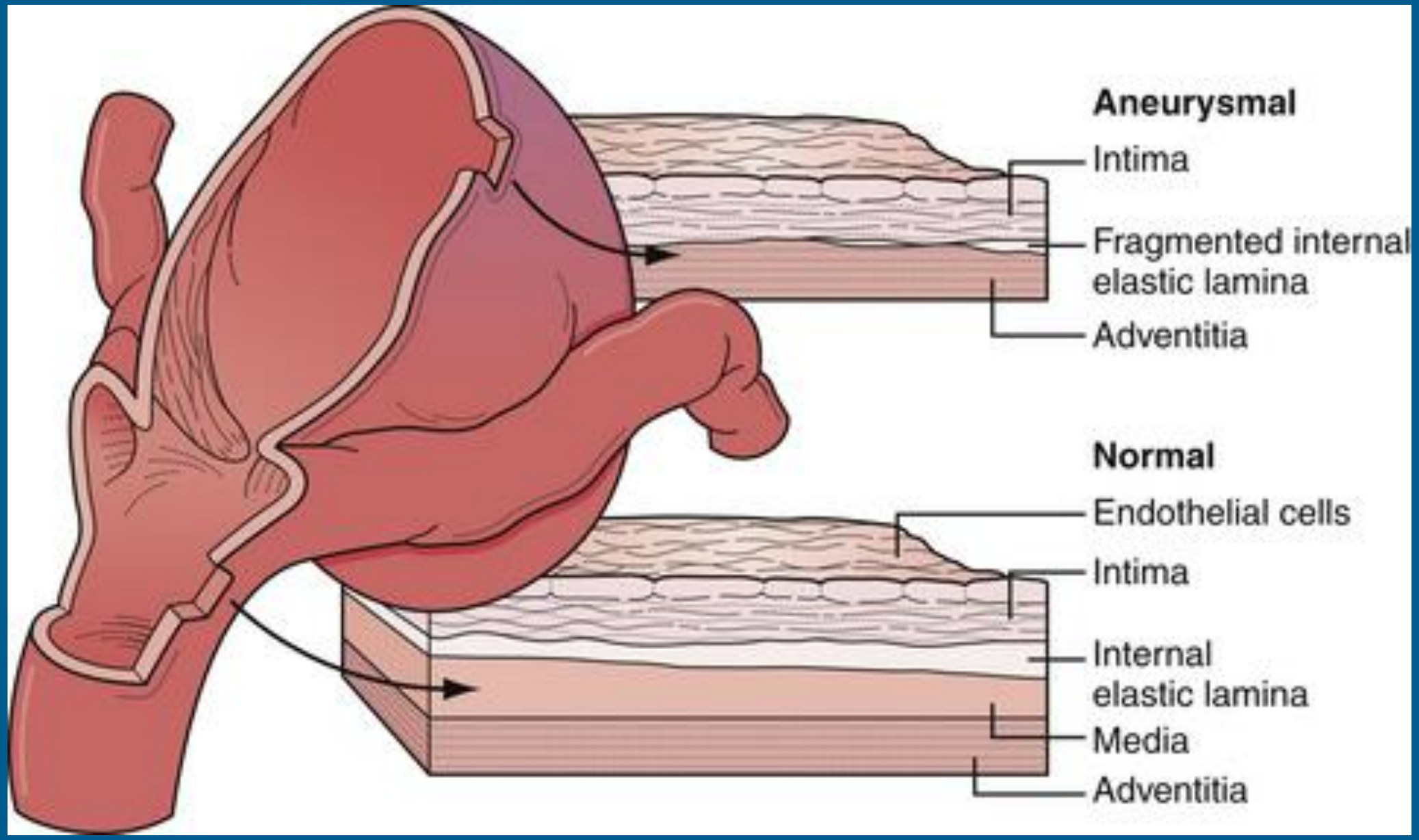


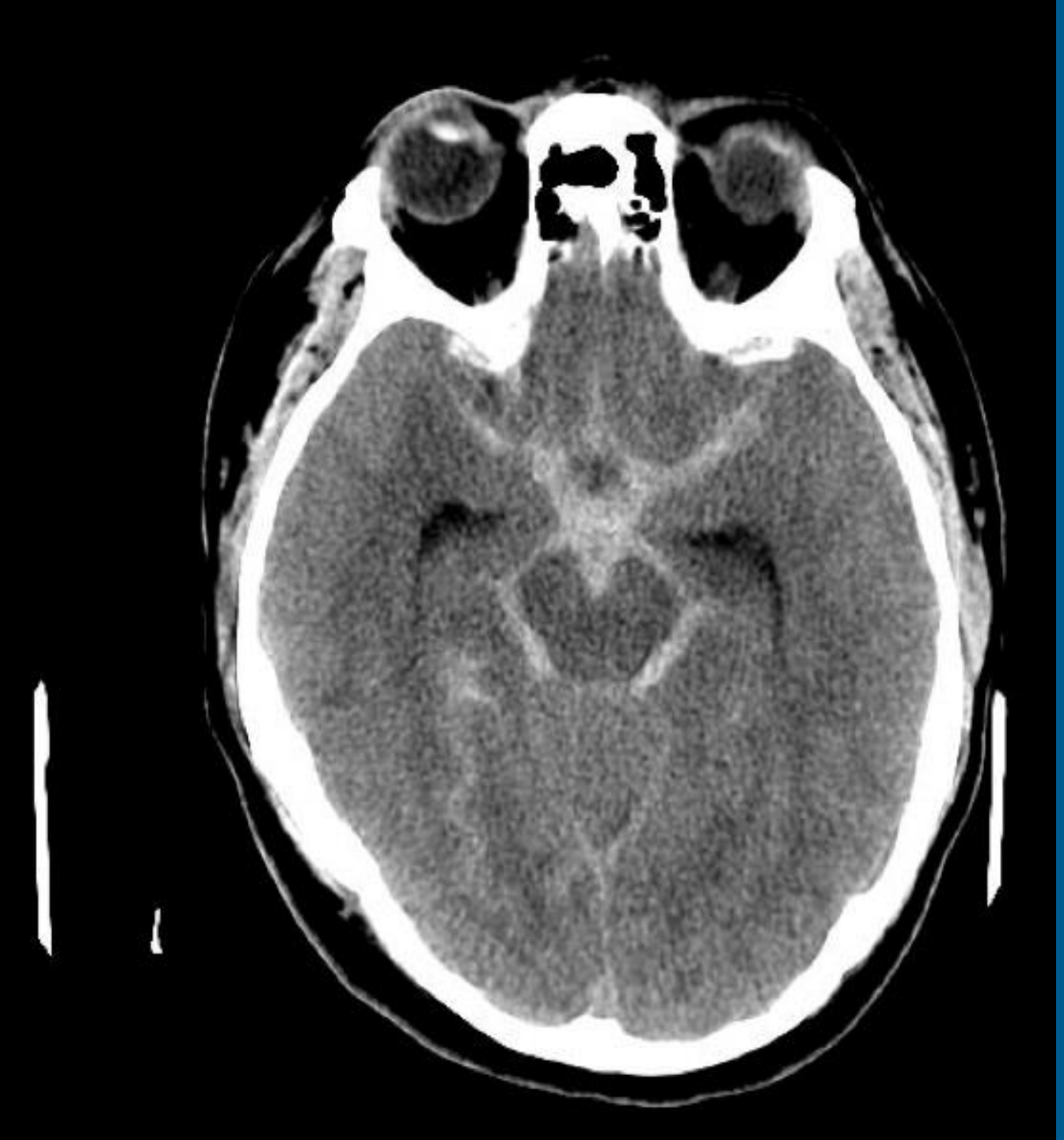
Aneurysm Locations

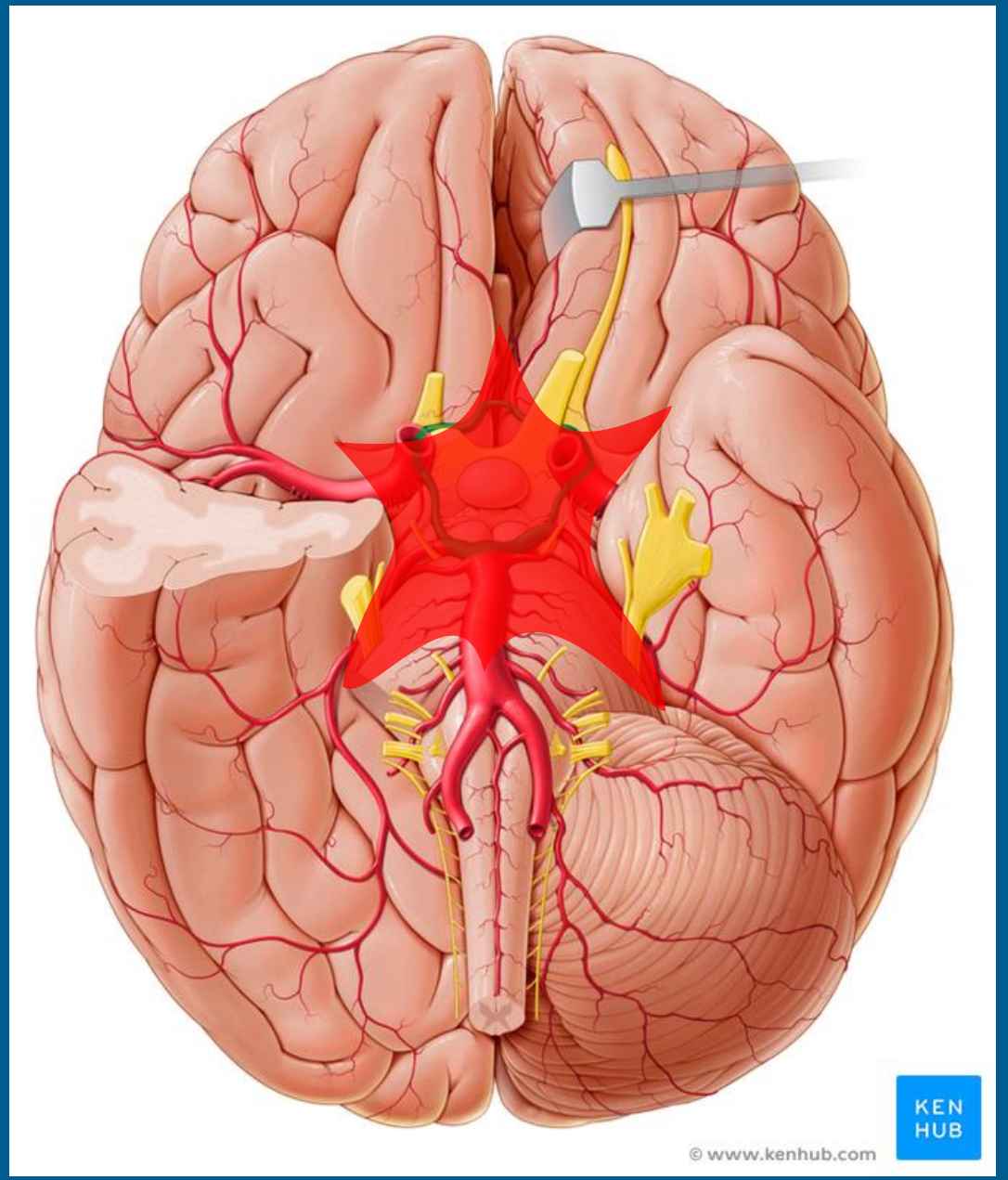

Skull
Aneurysm in artery
Dura mater
Arachnoid membrane
Subarachnoid space
Pia mater
Cerebral cortex


Saccular
Fusiform
Dissecting


Saccular Aneurysm
Fusiform Aneurysm
Ruptured Aneursym


Aneurysmal
Intima
Fragmented internal elastic lamina
Adventitia
Normal
Endothelial cells
Intima
Internal elastic lamina
Media
Adventitia

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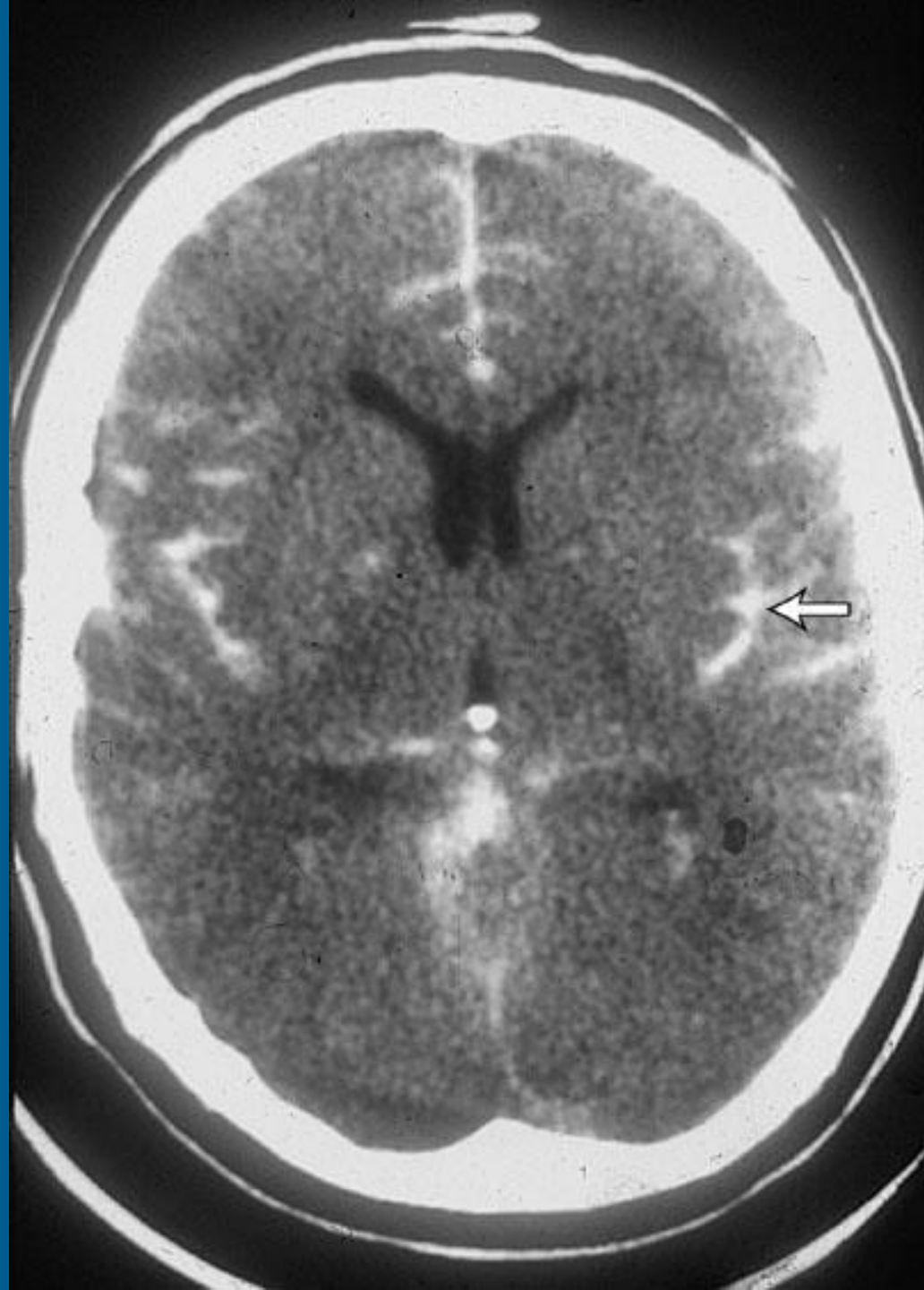
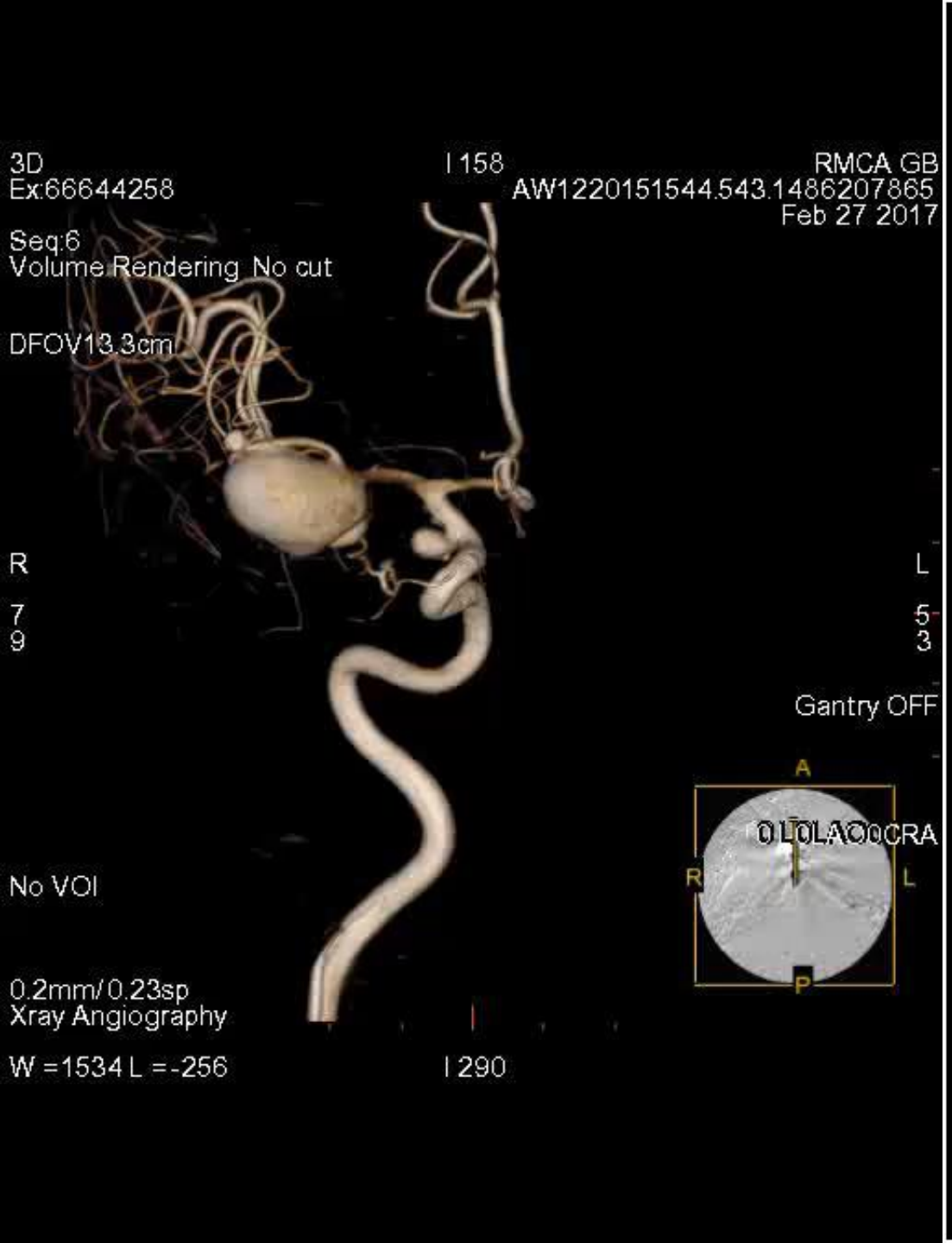
RISKS & ETIOLOGY

SUBARACHNOID HEMORRHAGE (SAH)

Subarachnoid Hemorrhage

- 14/100k-Annual incidence
- 1:1.24 male to female
- >50 year old
- 15-40% Prehospital deaths
- 20-30% in-hospital mortality
- 30-40% survive with good recovery
- 20-30% survive with severe disability




3D
Ex:66644258
I 158
RMCA GB
AW1220151544.543.1486207865
Feb 27 2017
Seq:6
Volume Rendering No cut
DFOV13.3cm
R
L
7
9
5
3
Gantry OFF
A
R
L
P
No VOI
0.2mm/ 0.23sp
Xray Angiography
W =1534 L =-256
I 290

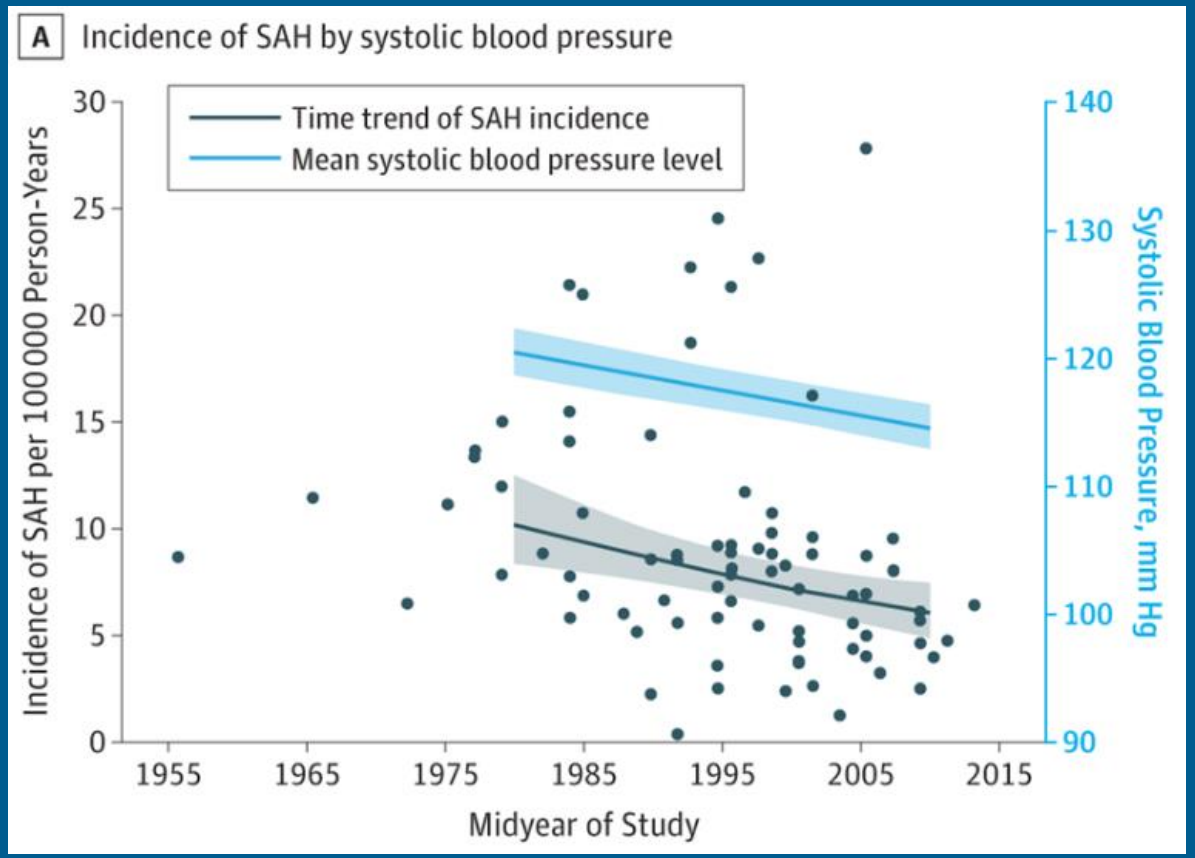
a.

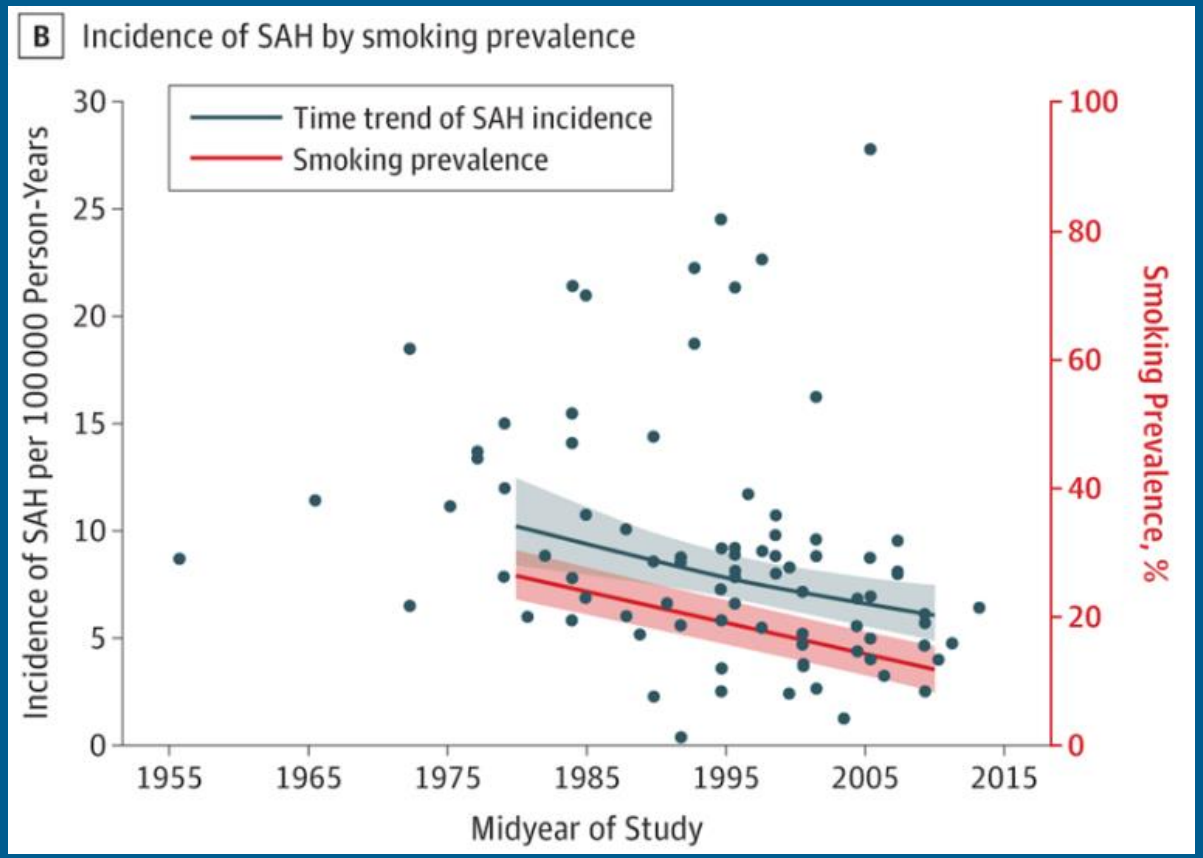
b.

c.

Risk Factors – Modifiable

- **Hypertension**
- **Smoking**


A
Incidence of SAH by systolic blood pressure
Time trend of SAH incidence
Mean systolic blood pressure level
Incidence of SAH per 100 000 Person-Years
Systolic Blood Pressure, mm Hg
Midyear of Study
0
5
10
15
20
25
30
90
100
110
120
130
140
1955
1965
1975
1985
1995
2005
2015


B
Incidence of SAH by smoking prevalence
Time trend of SAH incidence
Smoking prevalence
Incidence of SAH per 100 000 Person-Years
Smoking Prevalence, %
Midyear of Study
0
5
10
15
20
25
30
0
20
40
60
80
100
1955
1965
1975
1985
1995
2005
2015

Risk Factors Non-Modifiable

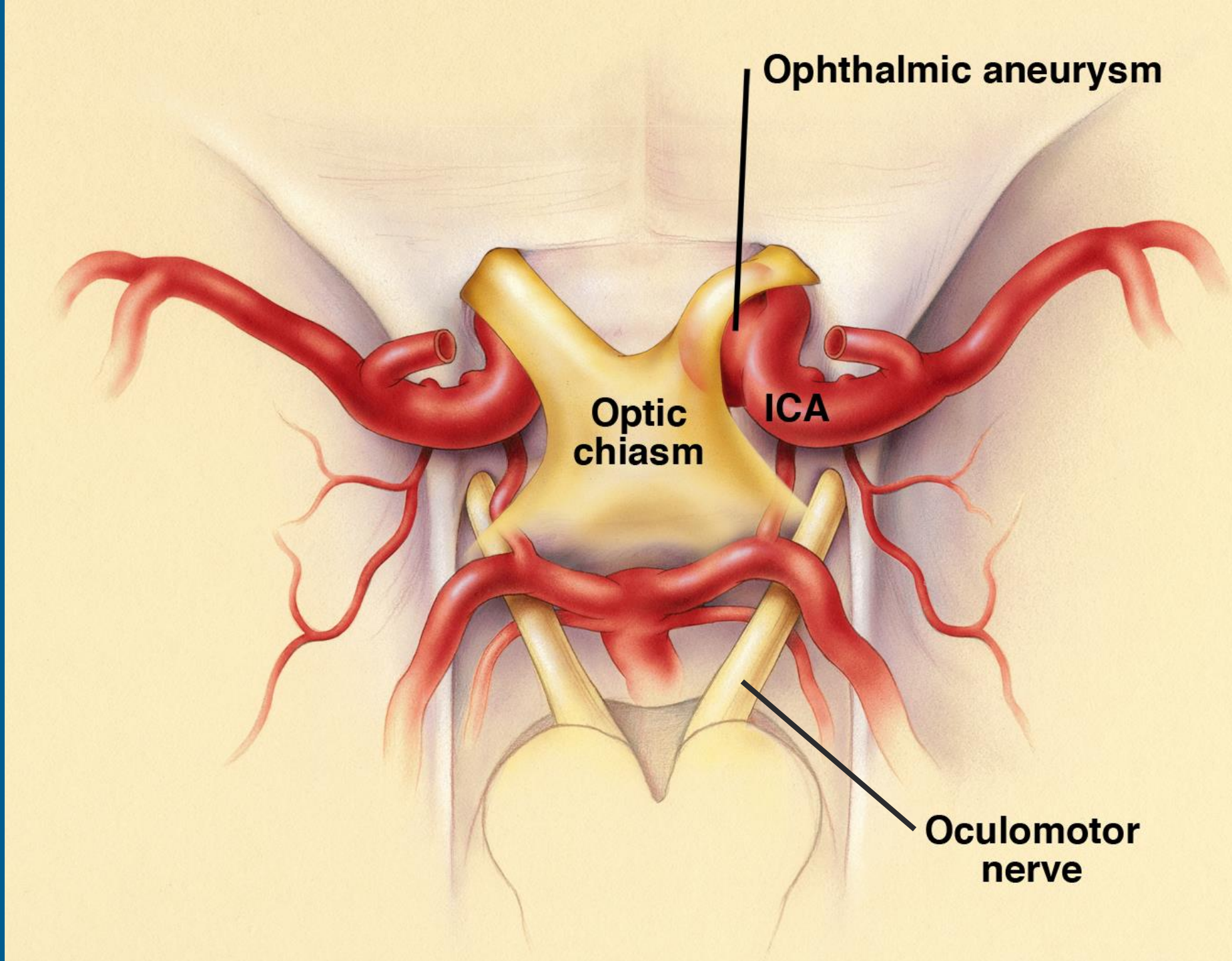
- Fibromuscular dysplasia (FMD)
- Pseudoxanthoma elasticum
- Ehlers-Danlos IV
- Marfan Syndrome
- Arteriovenous malformations (AVM)
- Familial intracranial aneurysm syndrome
- Gender
- Atherosclerosis
- Bacterial endocarditis
- Polycystic Kidney Disease

SIGNS & SYMPTOMS

ABRUPT HEADACHE!

STIFF NECK

CRANIAL NERVE PALSY



SAH Clinical Grading Scales

Grade	Hunt and Hess	WFNS
0		Intact aneurysm
1	Asxic / mild HA	GCS 15
1a	Fixed neuro deficit s men. or brain rxn	
2	Mod to sev HA, CN palsy, nuchal rigidity	GCS 13–14 no motor deficit
3	Lethargy, confusion, mild focal deficit	GCS 13–14 motor deficit
4	Stupor, hemiparesis, early decerebrate	GCS 7–12 +/- motor deficit
5	Coma, decerebrate, moribund	GCS 3–6 +/- motor deficit

Diagnostic Work Up

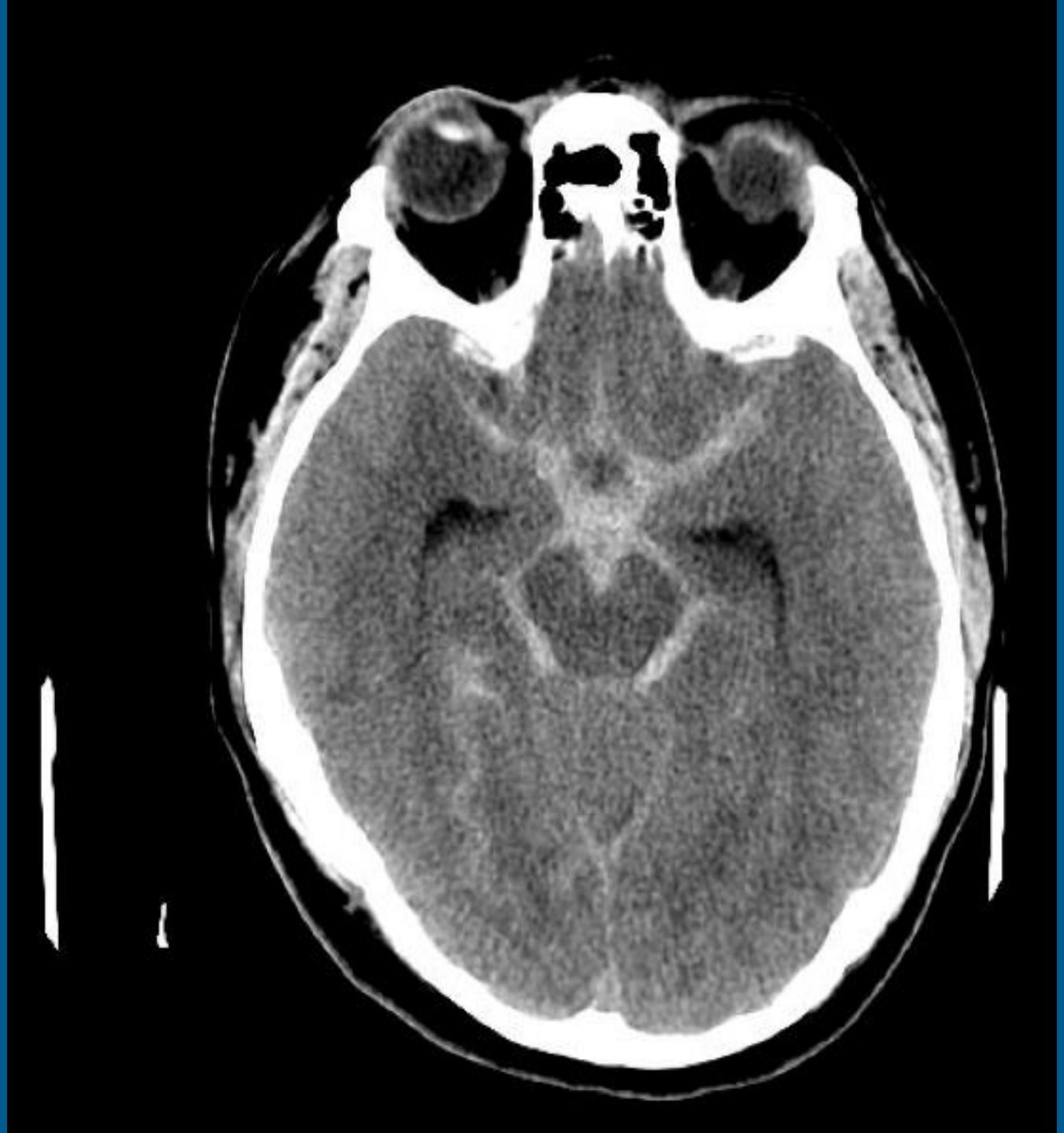
-Does the patient have SAH?

-Why does the patient have SAH?

Diagnostic Work Up

-Does the patient have SAH?

-Why does the patient have SAH?



CT

PROS	CONS
Rapid with ubiquitous availability	Less information about underlying lesions
No ferromagnetic contraindications (pacers)	Subtle hemorrhages may not be visualized
CT angiography	

MRI

PROS

Informs decision about underlying lesions

Exquisitely sensitive

- Especially GRE & SWI

Often part of diagnostic package at some point

CONS

Time to acquire image

- T2, GRE, DWI: 20 min, add SWI: another 15 min

Contraindications - implants

More expensive

Availability

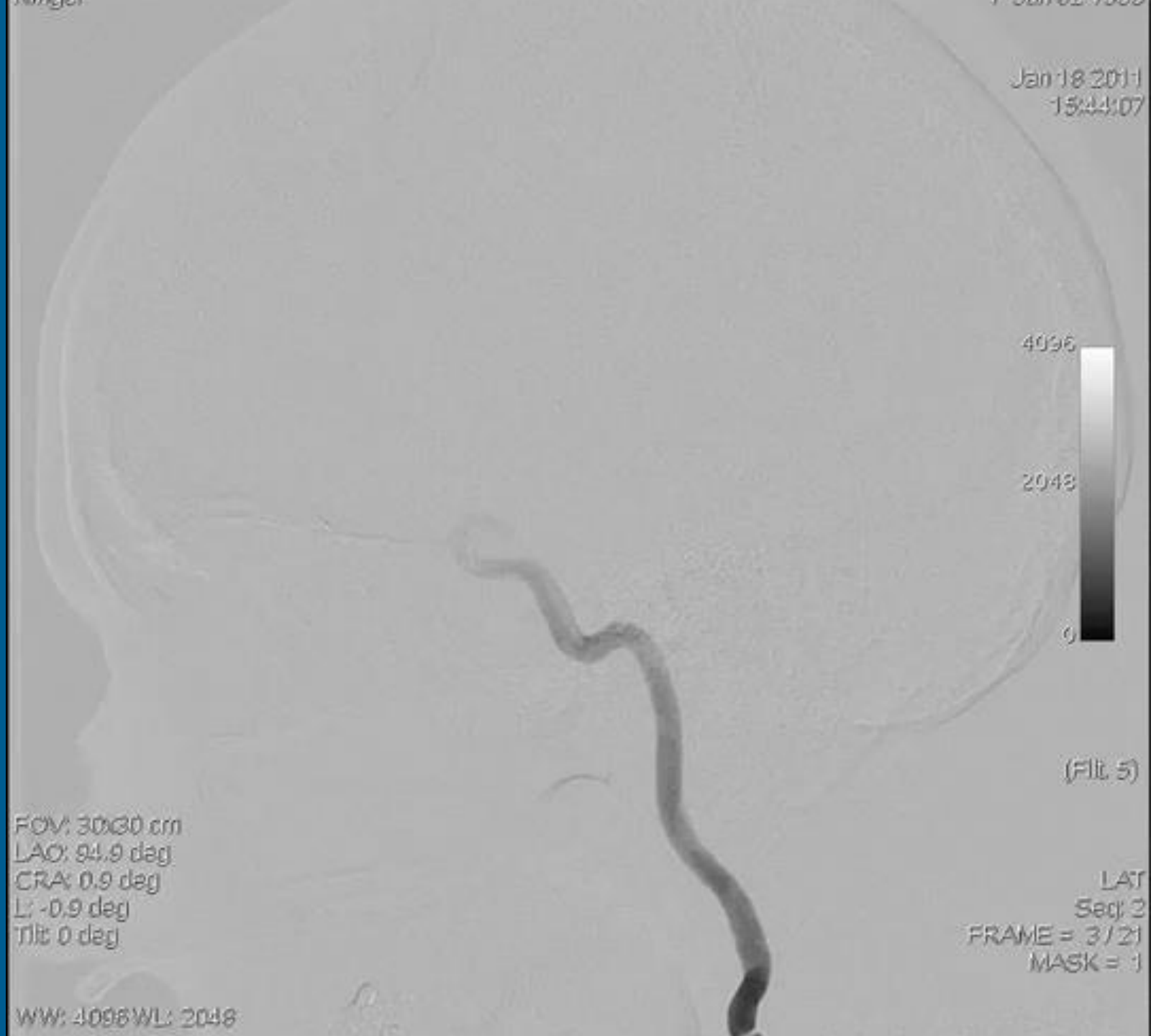
Lumbar Puncture

Diagnostic Work Up

-Does the patient have SAH?

-Why does the patient have SAH?

Conventional Angiography (DSA)



TREATMENT CONSIDERATIONS:

- **Prevent rebleeding – blood pressure control & secure the aneurysm**
  - Clip? Coil?
- **Manage associated neurological complications**
  - Seizures
  - Hydrocephalus
  - Vasospasm
- **Manage associated medical complications**
  - Ventilator management: ARDS, ALI, pneumonia; volume status; VTE; hyponatremia and other metabolic derangements; hyperglycemia; fever and infection diagnosis and treatment; cardiac arrythmia; etc.

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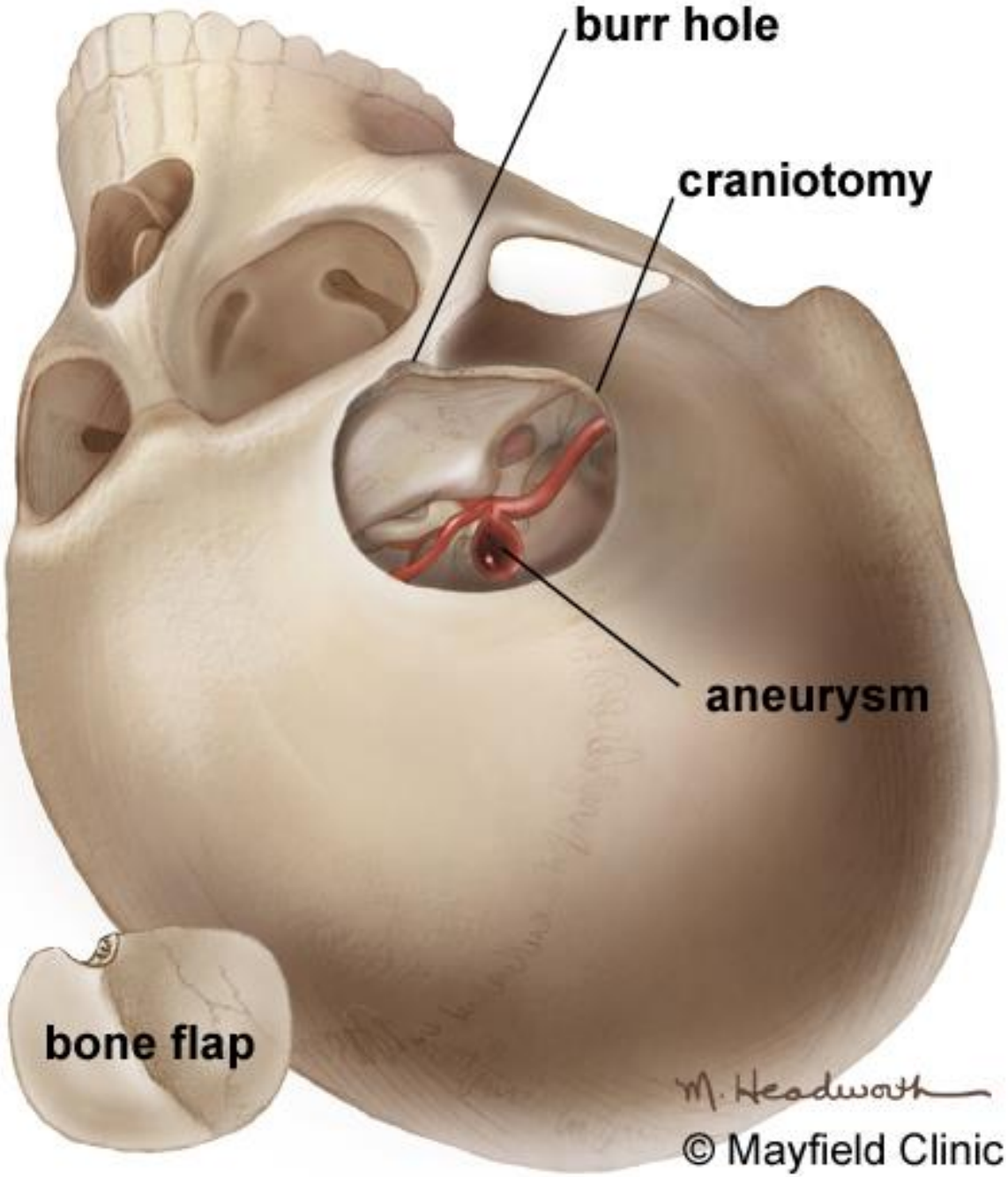
Considerations for Management

- Patient's condition
- Age
- Comorbidities
- Location
- Anatomy/Integrity
- Size & morphology
- Facility/Surgeon's ability
- Hematoma/ Mass effect



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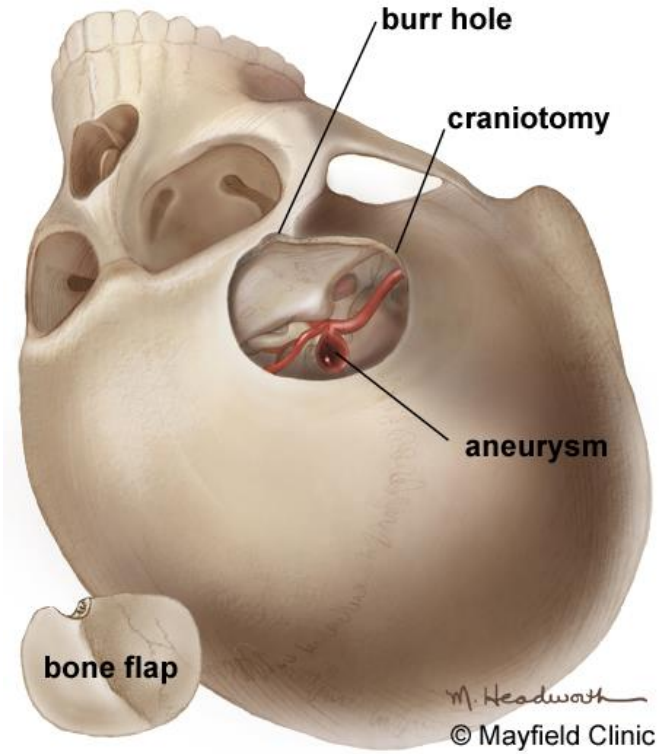
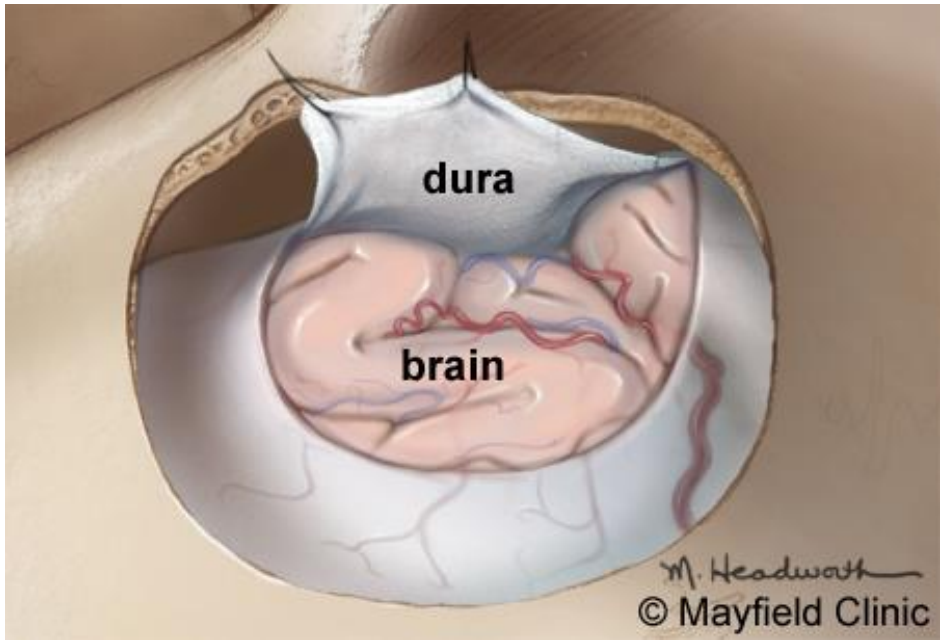
Brain & Spine


burr hole
craniotomy
aneurysm
bone flap
M. Headworth
© Mayfield Clinic


dura
brain
M. Headworth
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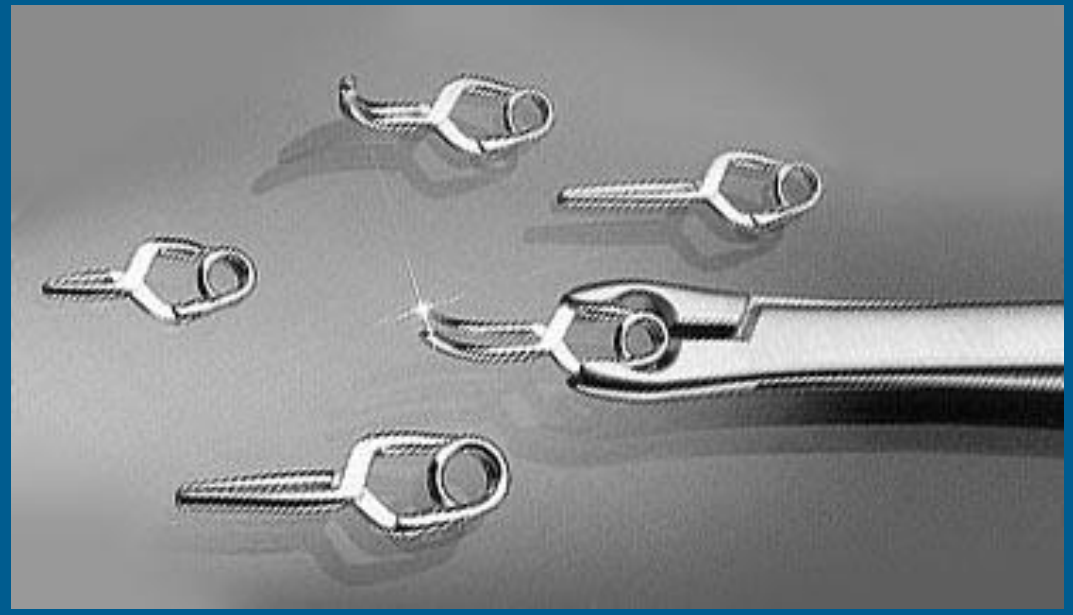


aneurysm clip
aneurysm
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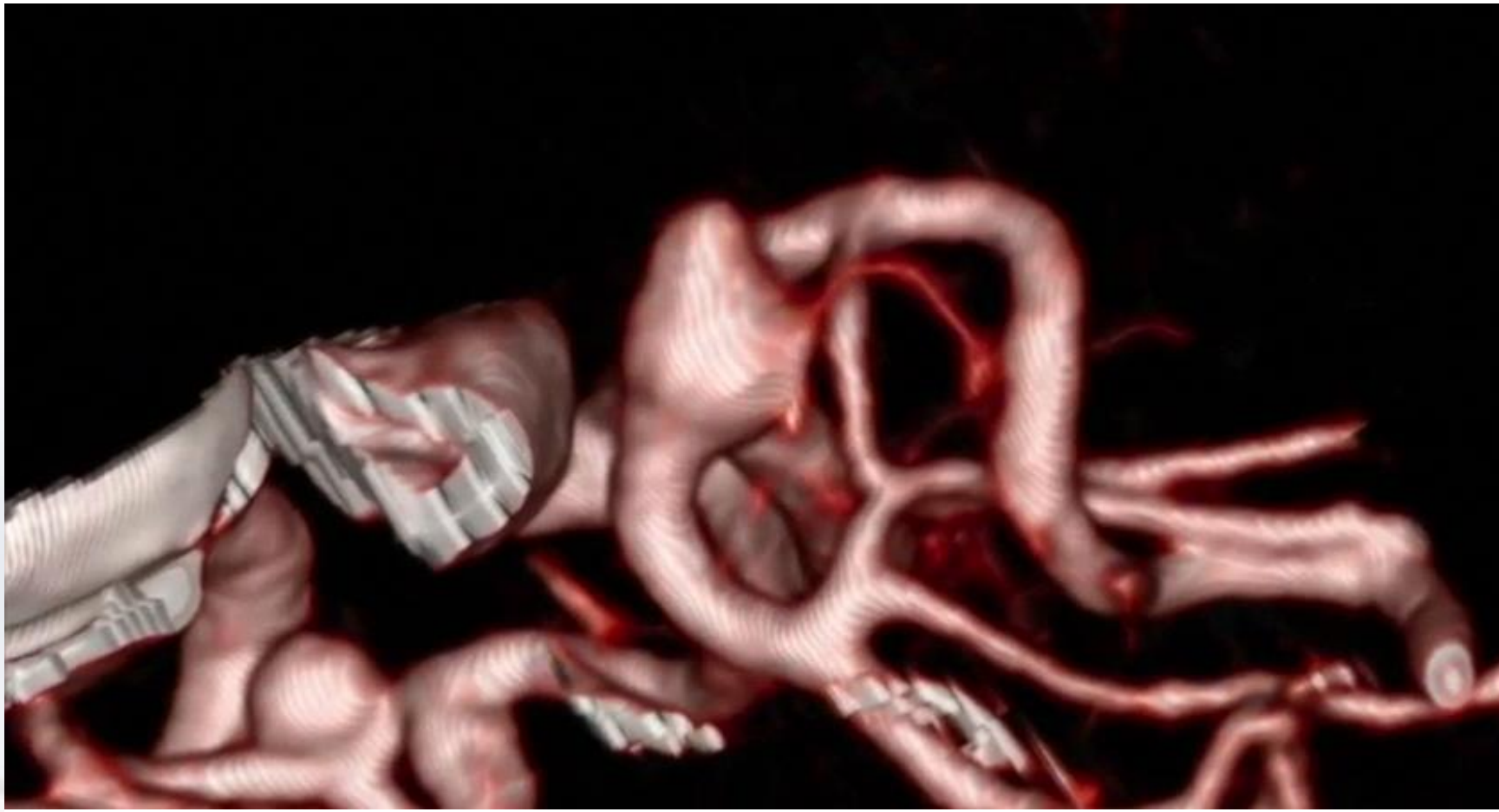
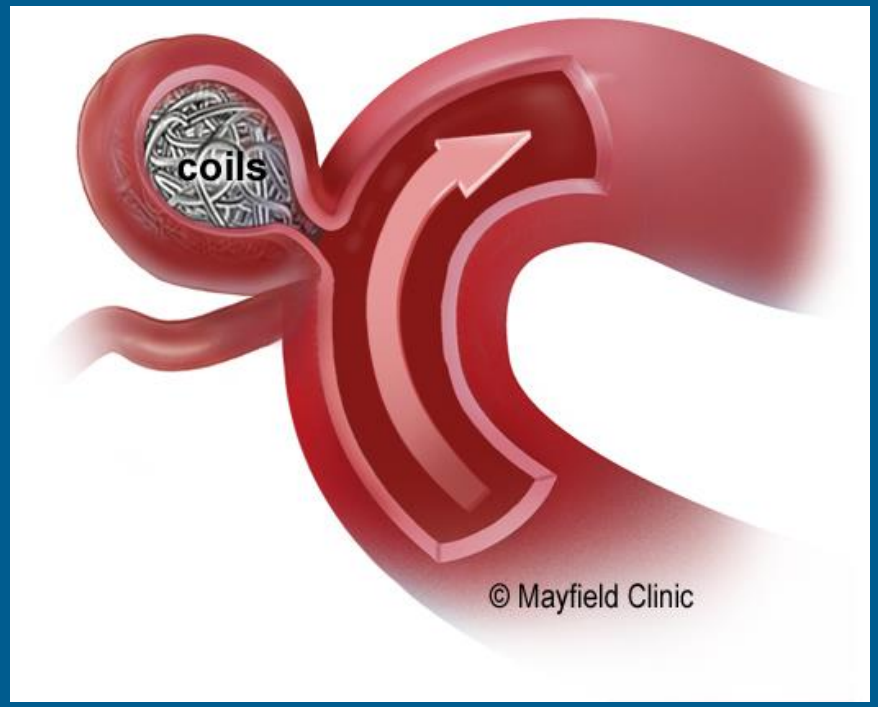
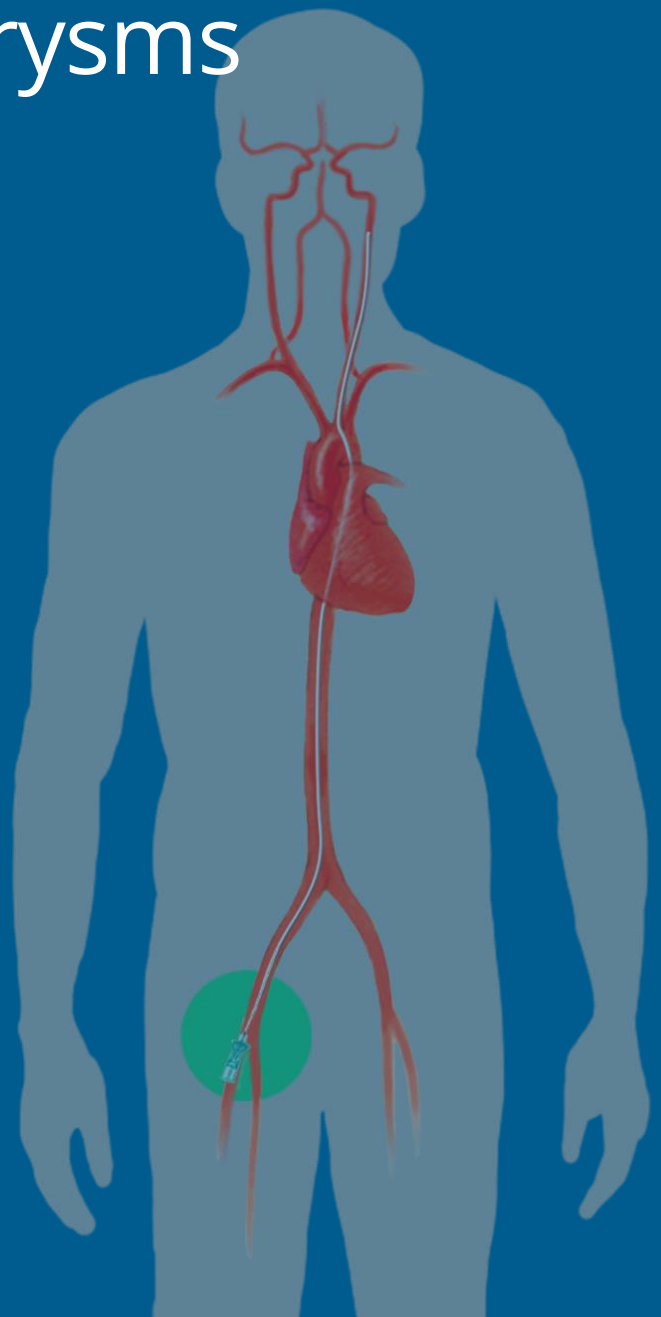



S
HFS
Compressed 4:1

Endovascular treatment of aneurysms

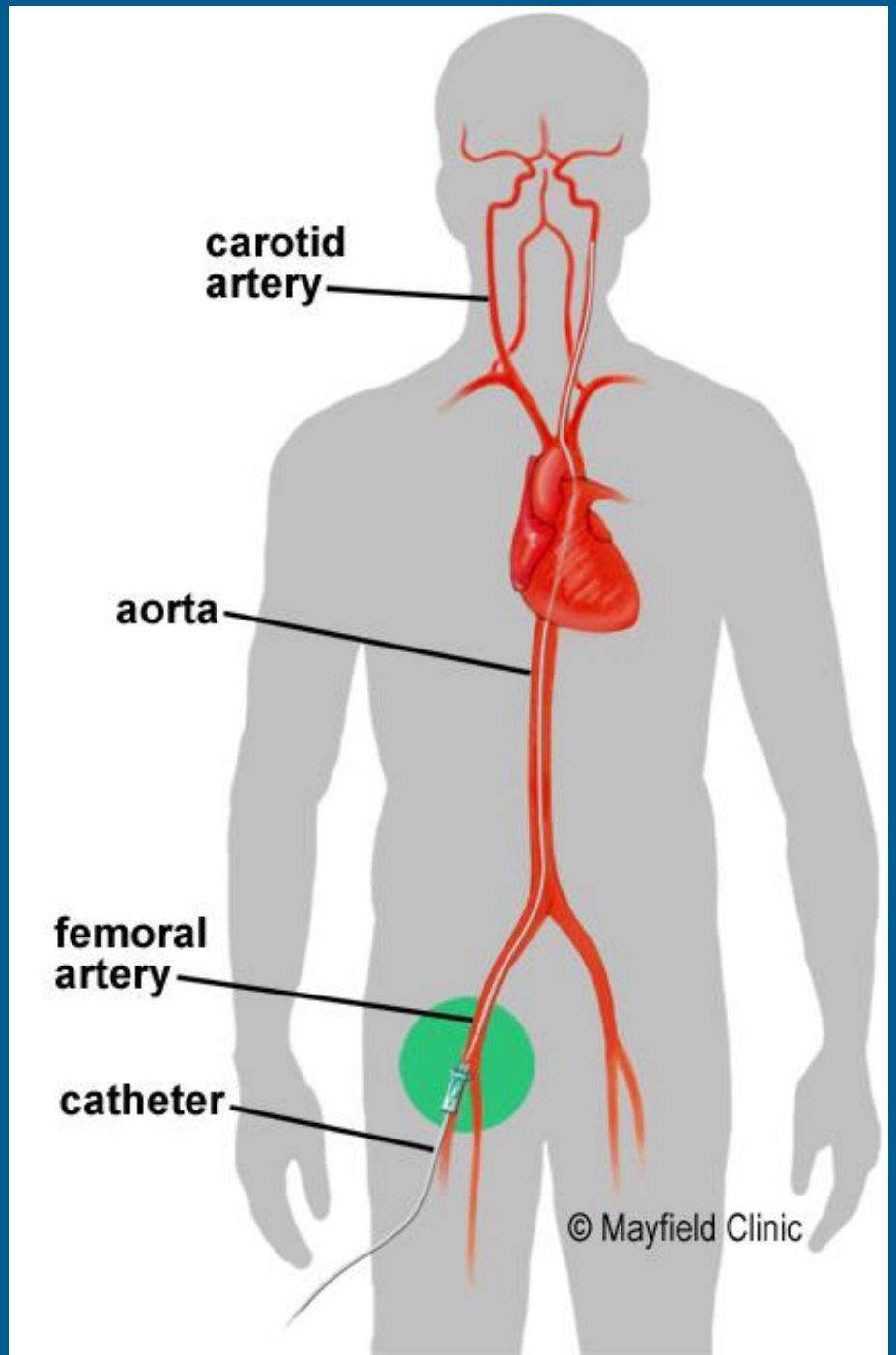
- Coiling
  - Angiographic procedure
  - Fill aneurysm with coils
  - Divert blood flow away from aneurysm





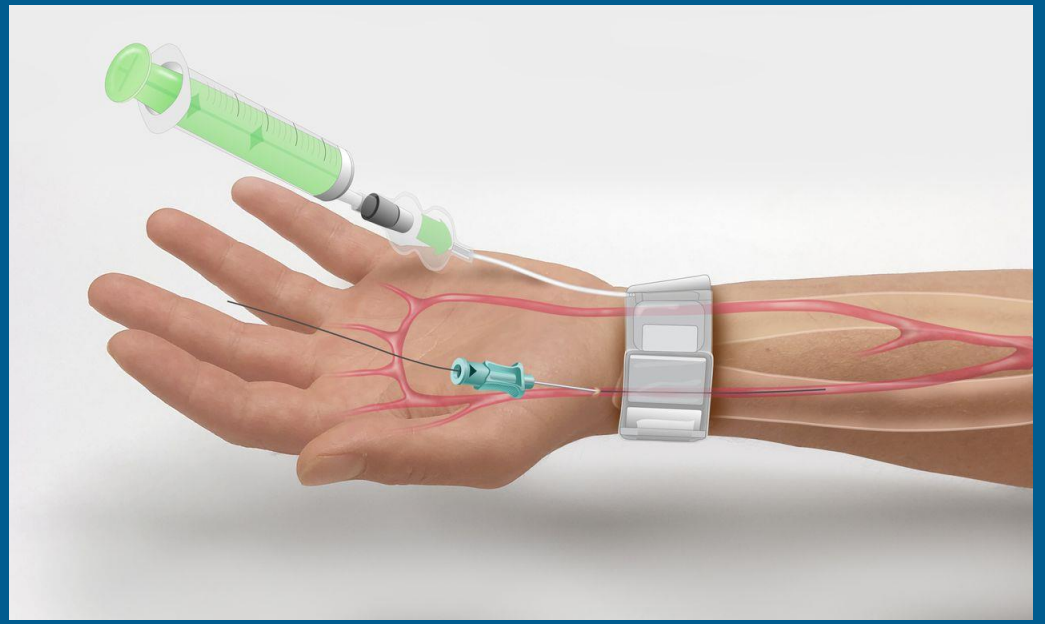
Angiography – femoral artery access

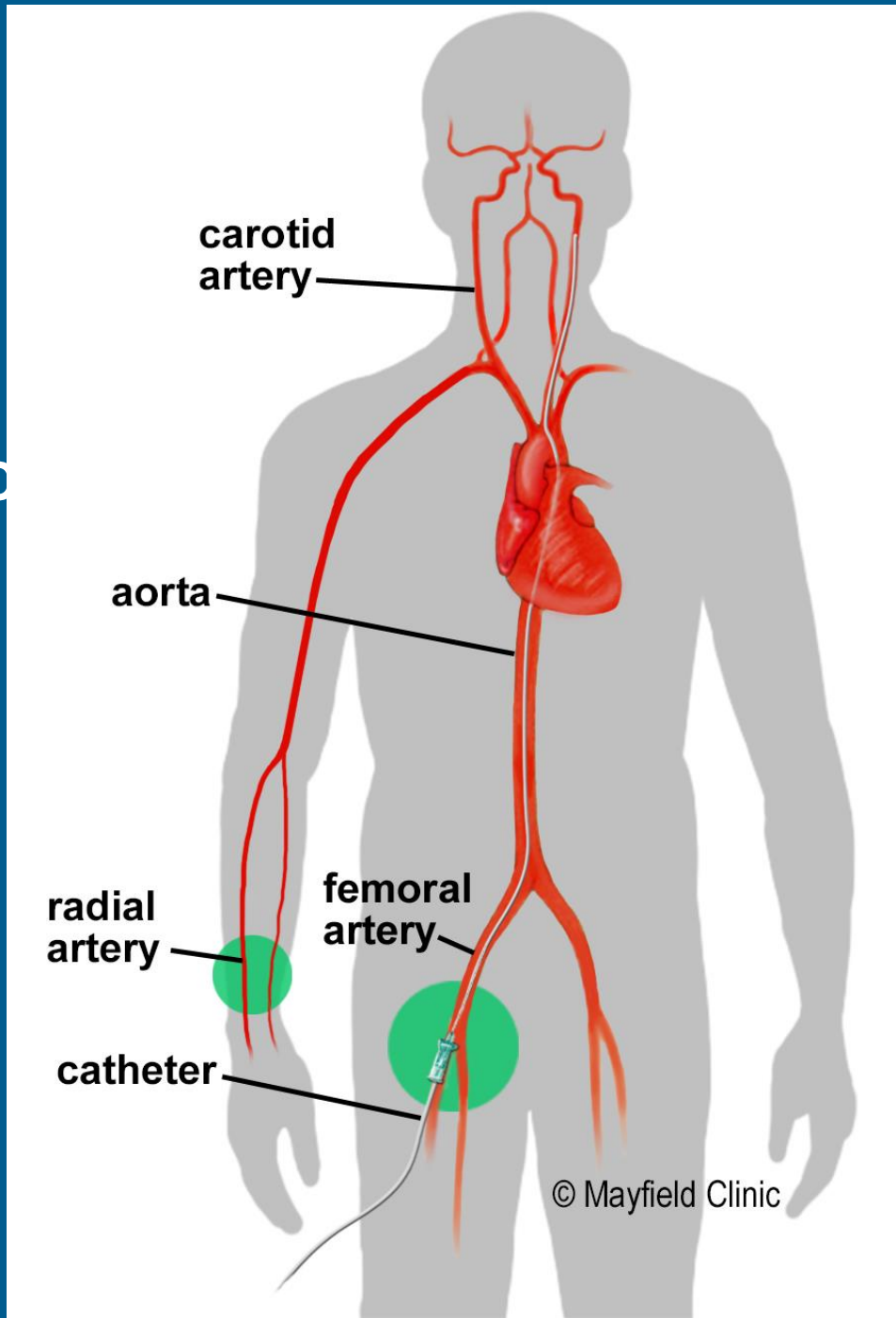
- Long, flexible catheter inserted into femoral artery in groin
- Manipulation of catheter up aorta to neck vessels
- When catheter is in correct place, contrast is injected as x-ray pictures are taken
- Process repeated to view all necessary arteries



Angiography – radial artery access

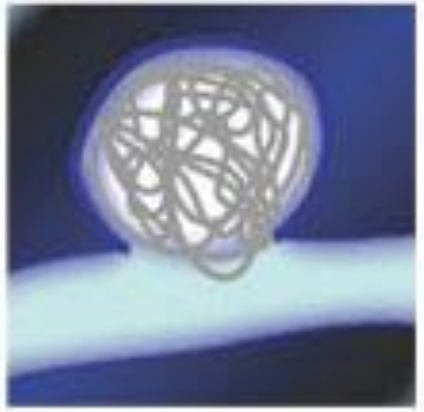
- Radial artery at wrist
- Less risk of bleeding
- Improves patient comfort compared to the femoral approach
- No need to stay off the leg to recover



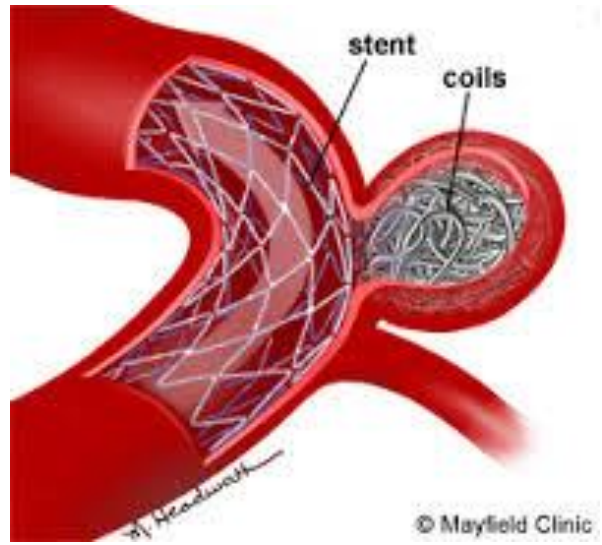


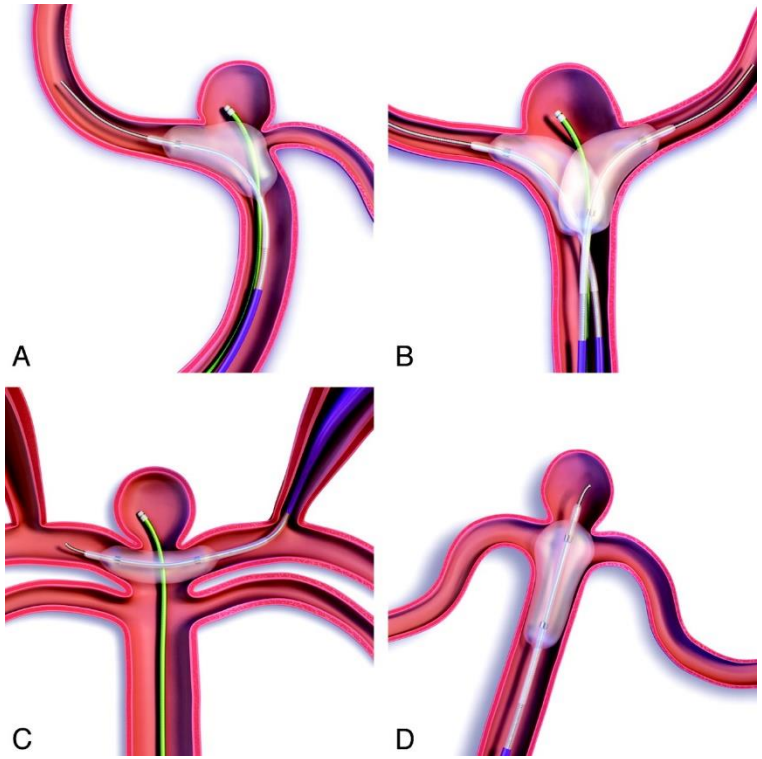
Introduction of catheter into aneurysm

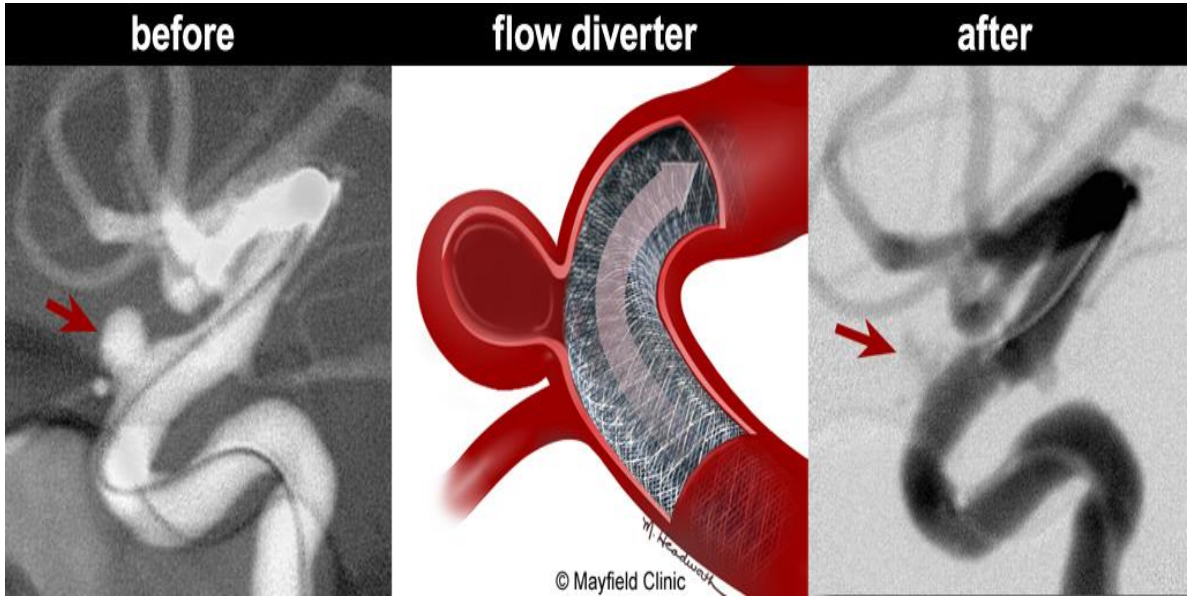
Insertion of coils into aneurysm via catheter

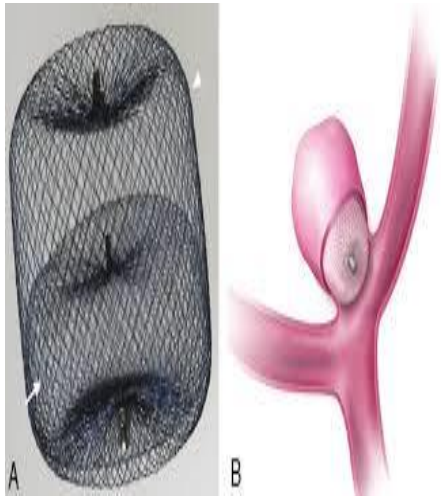


Aneurysm packed with coils









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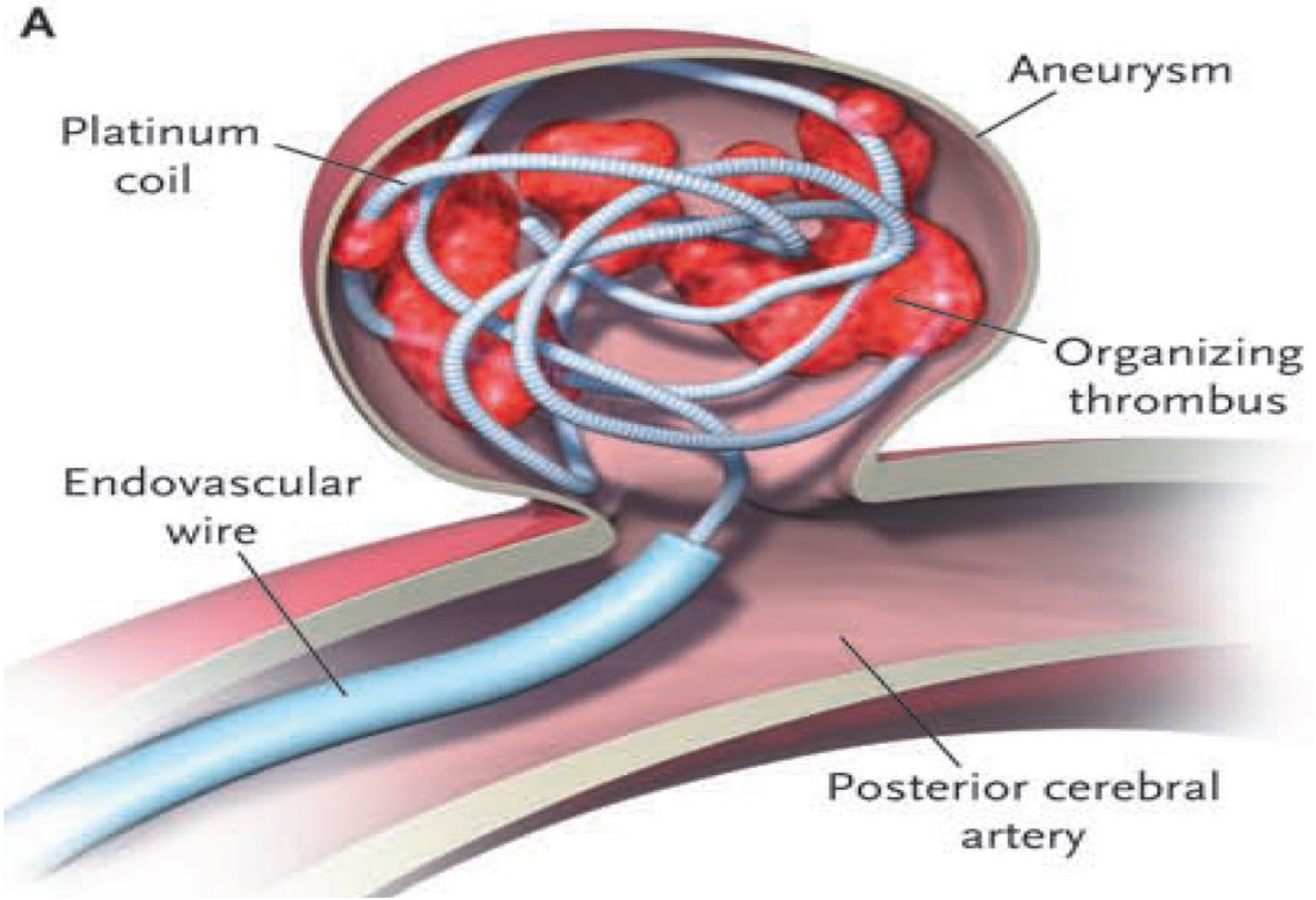
Brain & Spine


Right



Suarez (2005) New Engl J Med

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Brain & Spine

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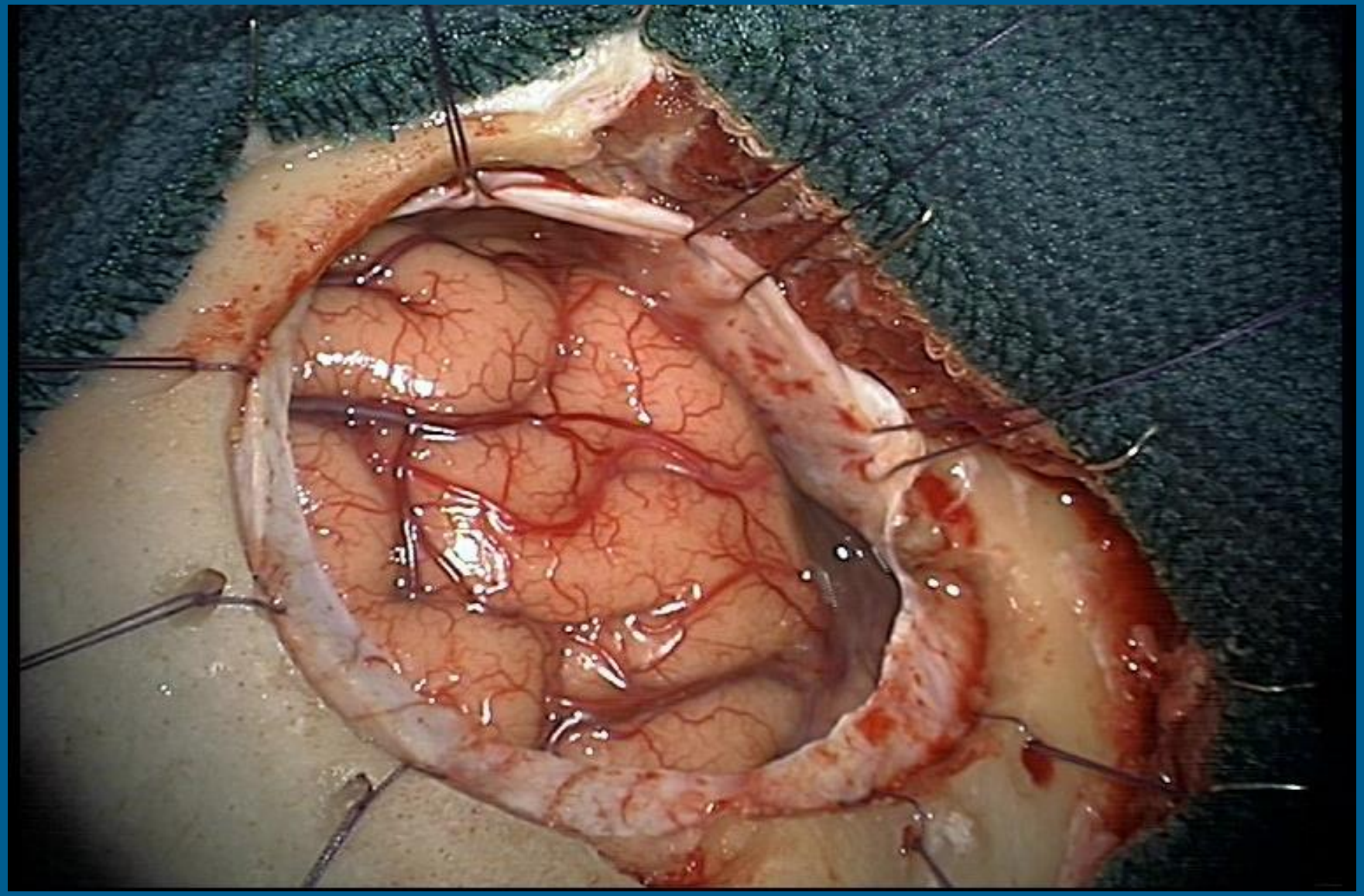
Brain & Spine

Why do open Surgery?



Surgical Indications

- Young patients
- Aneurysm size
- Large hematoma
- Aneurysm location
- Endo - unfeasible

TREATMENT CONSIDERATIONS:

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  - Clip? Coil?
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  - Seizures
  - Hydrocephalus
  - Vasospasm
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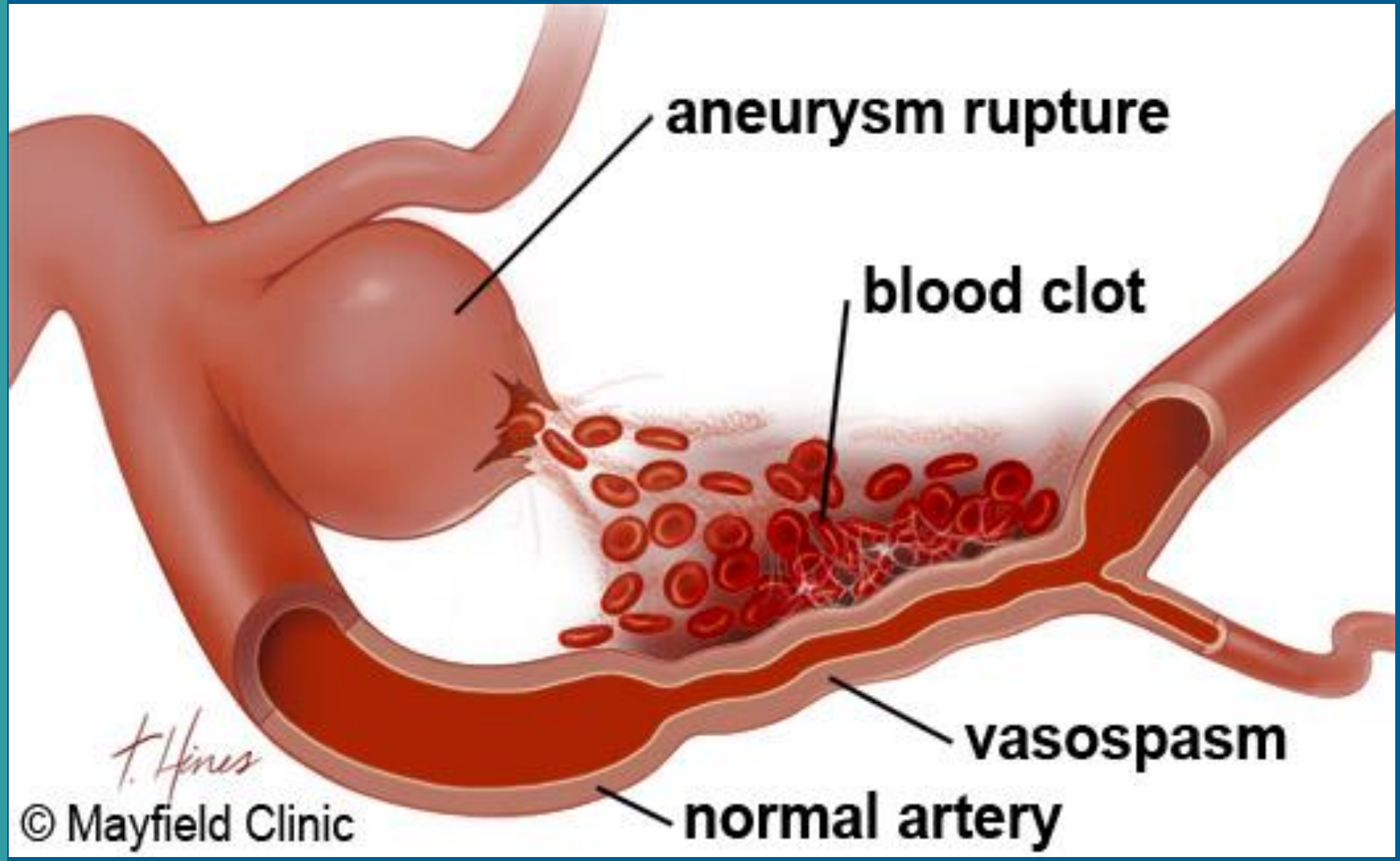
Cerebral Vasospasm



Cerebral Vasospasm

- 50-70% Radiographic
- 20-40% Clinical
- Onset 4 days post bleed
- Related to amount of blood

Severe Vasospasm Outcomes

- 30-40% cerebral infarction
- 30-40% mortality

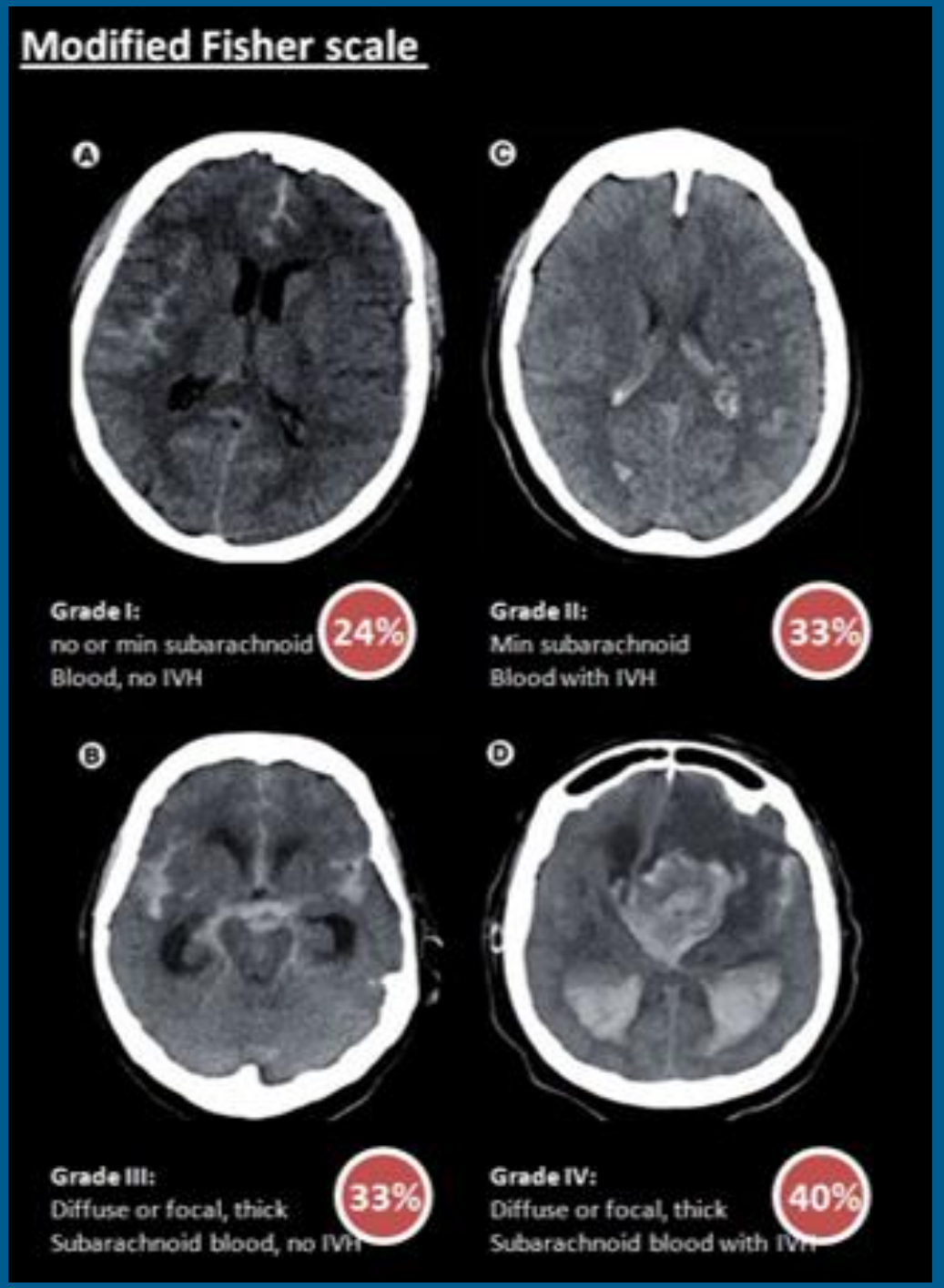
Delay Cerebral Ischemia (DCI)

21% of SAH patients develop delayed ischemia with no vasospasm

Only 20-30% of patients who develop vasospasm suffer of delayed ischemia

Early brain injury, micro vascular loss of autoregulation, cortical spreading depolarization, micro thrombosis

Amount of Hemorrhage



Clinical Presentation

- Asymptomatic – TCD's
- Decreased level of Consciousness
- New focal deficit
- Increasing headaches

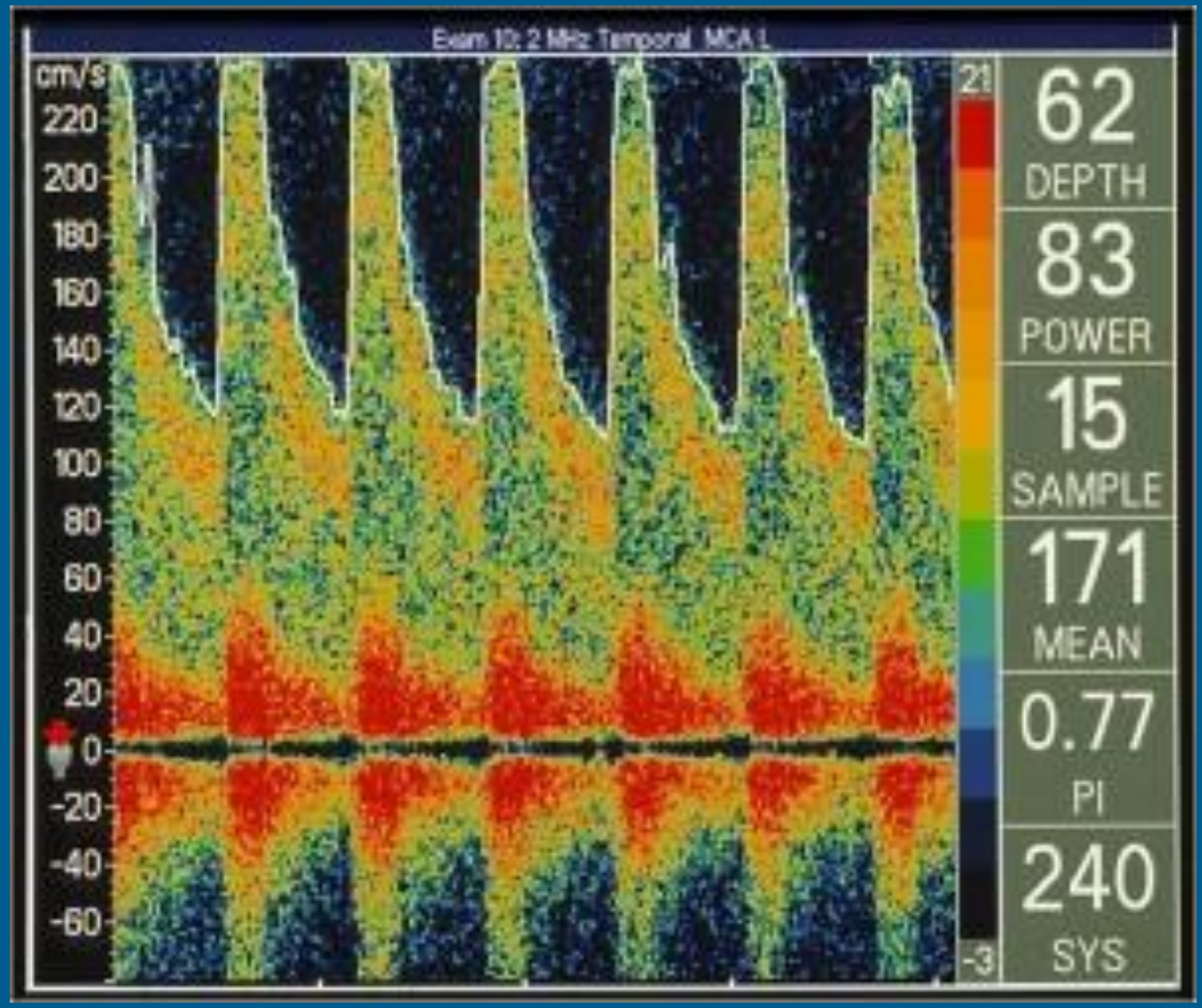
Work Up

- TCDs
- CTA
- Perfusion Imaging
- EEG
- DSA

Transcranial Doppler

- Sensitivity 48-73%
- Specificity 69-100%

Acta Inform Med. 2017 Mar; 25(1): 14–18
Neurology. 1989 Nov;39(11):1514-8.

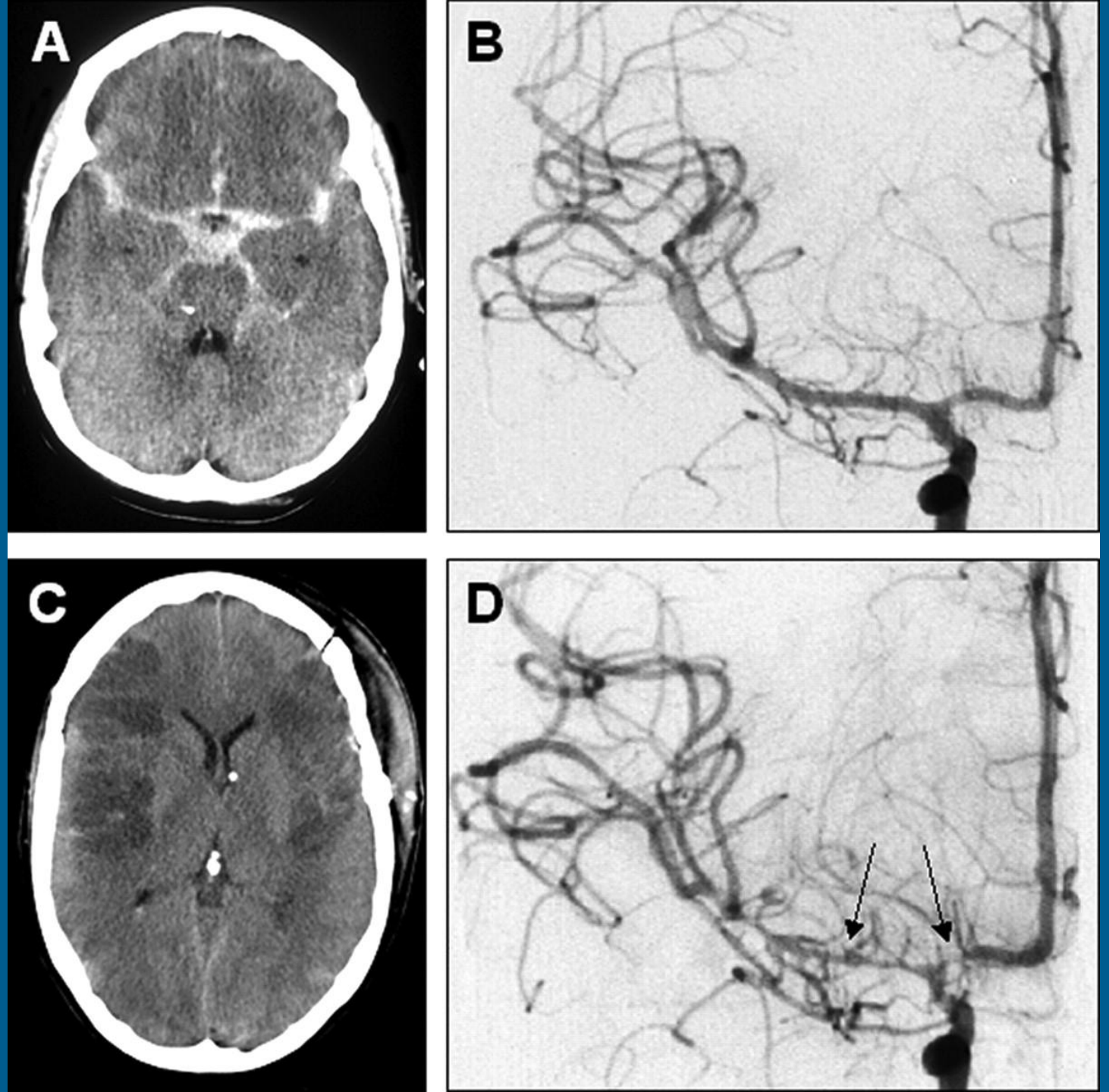


Vasospasm Mean velocities cm / sec	Terminal Carotid	Anterior Cerebral Artery	Middle Cerebral Artery	Vertebral Artery (VA)	Basilar Artery (BA)	Posterior Cerebral Artery	Lindegaard ratio (MCA/eICA)	BA/VA
Normal			<90				<3	
Above normal Hyperemia			90-119				<3	
Mild	>120	?	120-150	>60	>60	?	3-4	
Moderate	>130	?	150-199	>80	>80	>110	4-6	
Severe	?	> 50 % from baseline over 24 hrs	≥200	>80	>115	>110	>6	>3

bleed day 1, initial R ICA

bleed day 10, symptomatic R A1 vasospasm

post R A1 balloon angioplasty


A
B
C
D

Vasospasm Trials

Adv Biomed Res. 2017; 6: 83.
Published online 2017 Jul 14. doi: 10.4103/2277-9175.210660
PMCID: PMC5539667

The Effect of a Single dose Dantrolene in Patients with Vasospasm Following Aneurysmal Subarachnoid Hemorrhage

Masih Sabouri, Mahmood Momeni, Fariborz Khorvash,[1] Majid Rezvani, and Homayon Tabesh

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J Cereb Blood Flow Metab. 2017 Jan 1:271678X17724682. doi: 10.1177/0271678X17724682. [Epub ahead of print]

Long-acting statin for aneurysmal subarachnoid hemorrhage: A randomized, double-blind, placebo-controlled trial.

Naraoka M[1], Matsuda N[1], Shimamura N[1], Asano K[1], Akasaka K[2], Takemura A[3], Hasegawa S[4], Ohkuma H[1].

Neurocrit Care. 2014 Oct;21(2):356-64. doi: 10.1007/s12028-014-9964-0.

Prophylactic magnesium sulfate for aneurysmal subarachnoid hemorrhage: a systematic review and meta-analysis.

Reddy D[1], Fallah A, Petropoulos JA, Farrokhyar F, Macdonald RL, Jichici D.

Clazosentan, an endothelin receptor antagonist, in patients with aneurysmal subarachnoid haemorrhage undergoing surgical clipping: a randomised, double-blind, placebo-controlled phase 3 trial (CONSCIOUS-2)

Dr R Loch Macdonald, MD, Randall T Higashida, MD, Emanuela Keller, MD, Stephan A Mayer, MD, Andy Molyneux, MD, Andreas Raabe, MD, Peter Vajkoczy, MD, Isabel Wanke, MD, Doris Bach, MSc, Aline Frey, PharmD, Angelina Marr, BSc Pharm, Sébastien Roux, MD, Neal Kassell, MD

Published: 02 June 2011

Cerebrovasc Dis. 2017 May 3; 44(1-2): 59–67.
Published online 2017 May 3. doi: 10.1159/000475824
PMCID: PMC5475234

Preventive Effect of Clazosentan against Cerebral Vasospasm after Clipping Surgery for Aneurysmal Subarachnoid Hemorrhage in Japanese and Korean Patients

Miki Fujimura,[a,*] Jin-Yang Joo,[c] Jong-Soo Kim,[d] Motonori Hatta,[b] Yoshinari Yokoyama,[b] and Teiji Tominaga[a]

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Vasospasm Trials

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Trials Outcomes

Francoeur and Mayer Critical Care (2016) 20:277

Table 2 Selected pharmacologic interventions that have been evaluated for DCI prevention[a]

Intervention	Effect
Aspirin	No effect on new lesion associated with neurological worsening [103]
Clazosentan	No effect on mortality or vasospasm-related morbidity [5]
Enoxaparin	No effect on DCI or GOS at 3 months [104]
Erythropoietin	Less neurological deficit with cerebral infarct; no difference in mRS or GOS at 6 months [105]
Fludrocortisone	No effect on incidence of cerebral ischemia or independent living [27]
Magnesium	No difference in mRS at 3 months [106]
Methylprednisolone	No effect on neurologic worsening; trend towards better GOS at 6 months [107]
Nicardipine	No effect on neurological worsening or GOS at 3 months [102]
Prophylactic angioplasty	No effect on new neurologic deficits or GOS at 3 months [86]
Prophylactic hypervolemia	No effect on neurologic worsening or GOS at 3 months [69]
Statins	No effect on DCI, death or mRS at 6 months [108]

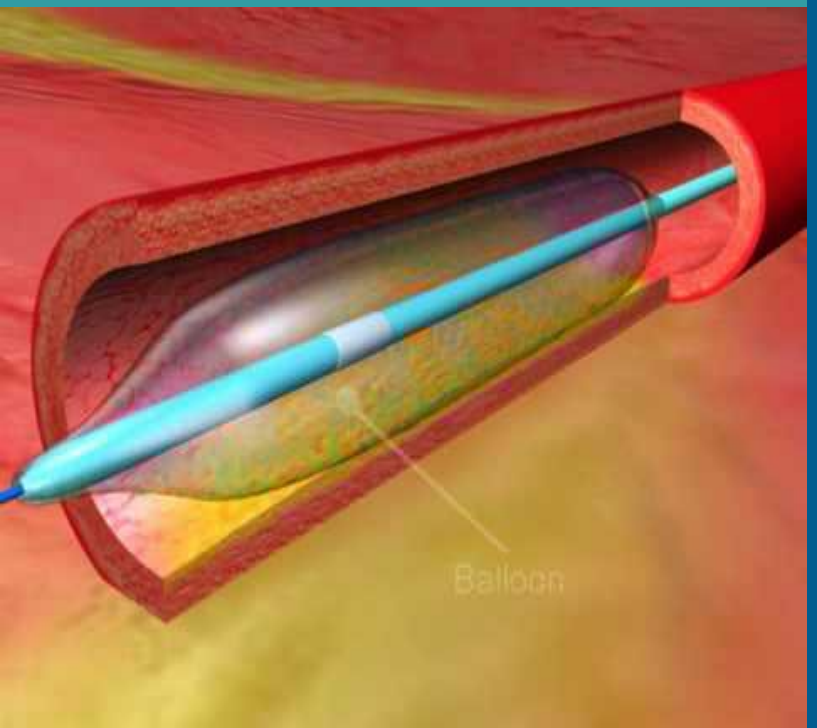
[a]Excluding nimodipine. Only randomized controlled trials are considered. References are either the most recent, most definitive, or most robust trial according to the authors' opinion

DCI delayed cerebral ischemia, *GOS*, Glasgow Outcome Scale, *mRS* modified Rankin Scale

Vasospasm Management

- Rule out Mimics
- Hemodynamic augmentation HH+(Euvolemia/mild hypervolemia)
- Increase perfusion, MAP - Norepinephrine, Dopamine
- Milrinone infusion
- Nimodipine - Neuroprotective

Endovascular Management



- Patients who fail medical management
- Patients with CTA/DSA showing severe vasospasm
- Intra-arterial verapamil
- Balloon angioplasty
- Intrathecal Nicardipine

OUTCOMES

The Barrow Ruptured Aneurysm Trial

Clinical article

Cameron G. McDougall, M.D.,[1] Robert F. Spetzler, M.D.,[1] Joseph M. Zabramski, M.D.,[1] Shahram Partovi, M.D.,[2] Nancy K. Hills, Ph.D.,[3] Peter Nakaji, M.D.,[1] and Felipe C. Albuquerque, M.D.[1]

TABLE 3: Proportion of patients with poor outcome (mRS score > 2) at 1 year in the BRAT

Clip Group			Coil Group				
Subgroup	No.*	No. w/ mRS Score >2 (%)	Subgroup	No.*	No. w/ mRS Score >2 (%)	OR (95% CI)	p Value
assigned clip	205	69 (33.7)	assigned coil	198	46 (23.2)	1.68 (1.08–2.61)	0.02
assigned clip & received clip	180	61 (33.9)	assigned coil & received coil	109	20 (18.4)	2.28 (1.30–4.13)	0.005
crossover: assigned coil & received clip	65	22 (33.9)	crossover: assigned clip & received coil	4	3 (75.0)	0.17 (0.01–1.42)†	0.14
total actually treated w/ clip	245	83 (33.9)	total actually treated w/ coil	113	23 (20.4)	2.01 (1.20–3.46)	0.01

* Total number of patients in each category in whom the mRS score at 1 year was available.

† Reference group; those assigned to coil embolization who crossed over to surgical clipping.

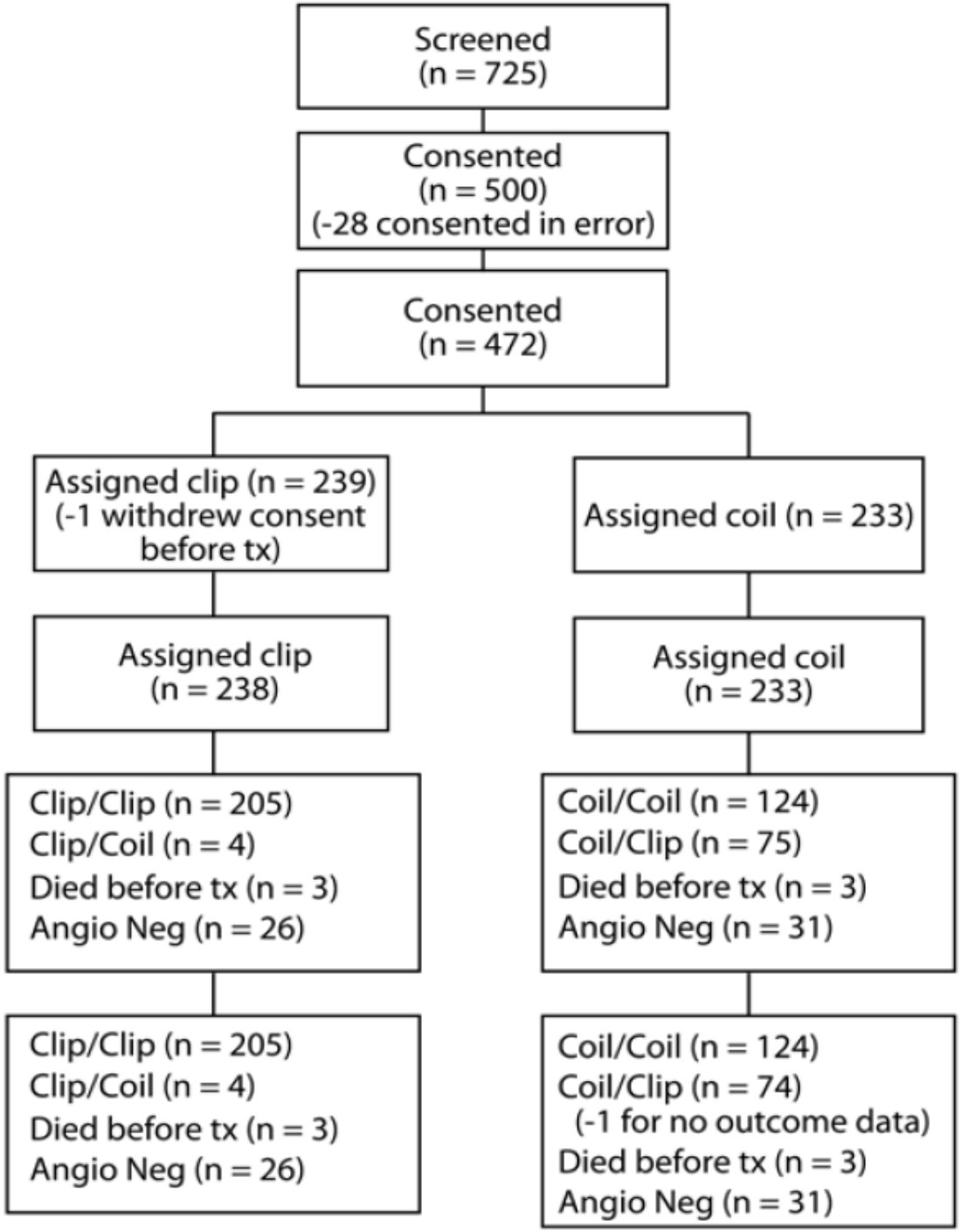


TABLE 4: Multivariable analysis of patients with poor outcome (mRS score > 2) at 1 year in the BRAT

Characteristic	OR (95% CI)	p Value
clipping*	1.72 (1.09–2.76)	0.020
age >50 yrs	2.03 (1.23–3.42)	0.007
Hunt & Hess grade >II†	3.51 (2.21–5.68)	<0.0001

Durability at 10 years

BRAT (Barrow Ruptured Aneurysm Trial)

@ 10 years	Coil	Clip
Residual	78%	7%
Retreatment	20%	1%
Re-hemorrhage	0%	0%

Summary

- **Subarachnoid hemorrhage can be a devastating disease**
- **Aneurysms occur at weak areas of the vessel wall**
- **Multiple factors and conditions associated**
- **CT, MR, and DSA are the main diagnostic tools**

Summary

Technological advances and better modern neurocritical care is crucial

Both medical and surgical management play an important role

Management varies based on the patient, aneurysm, and surgeon skills

Summary

- **Vasospasm is responsible for significant morbitity / mortality**
- **Clinical suspicion is essential**
- **Most trials demonstrate no effect on clinical outcomes**
- **Management includes medical & interventional therapies**

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Questions

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